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OPTICAL SWITCH EVALUATION SUPPORT

Syracuse University

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Griffiss Air Force Base, New York

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13. ABSTRACT (Maximum 200 words)
Extensive testing has been done on nonlinear interface optical switch (NIOS) devices fabricated from laser deposited nonstoichiometric tunsten oxide films. A Fresnel coefficient formalism for evaluating the indices of refraction of the films has been developed. Three cycles of testing involving changing the tungsten-oxygen stoichiometry have not produced extremely large photorefractive effects. It was decided, after using a mathematical model to determine the required incident and reflection angles, to make the next set of NIOS devices from a film deposited on ZnS prisms. ZnS more closely matches the low light intensity index of the films. Preliminary studies of further changes to produce stronger nonlinearity have been performed. Raman spectroscopy showed that these films heated in oxygen organize themselves into octohedra, which are thought to be necessary for the photorefractive effects observed in titanates and niobates. Heating the films in vacuum produces blue films which ESCA shows contain tungsten in the +4 oxidation state. Such electron rich species might be able to provide highly polarizable charge carriers. In addition to use as optical switches, use of these films to make reconfigurable Dammann gratings has been studied. These gratings would allow optical addressing of large size S-SEED arrays.

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Introduction-Purpose

Substantial progress was made in testing optical switches, in particular nonlinear interface switches. Of equal importance was the goal of developing and optimizing methodology and apparatus for testing optical switches in general. We performed extensive testing of nonlinear interface switches to determine whether the predictions of size enhancements of nonlinear optical properties of cluster films are true.

In order to accomplish testing of many types of switches, it is necessary to produce picosecond laser pulses with highly correlated spatial, spectral and temporal properties. We needed to develop the capability of contacting light to the active regions of switches with great precision($\pm 10\mu m$). To attain sufficient precision, accuracy, speed and reproducibility, computer control is essential. Extensive work was done to configure apparatus so as to achieve a sufficiently flexible mechanical mounting capability and a sufficiently flexible computer software "infrastructure" to facilitate testing of an arbitrary choice of switch.

In this effort, we chose to test nonlinear interface switches because these types of switches have already been shown to have excellent characteristics for digital optical computing applications if they can be fabricated with materials having better nonlinear optical properties than earlier versions. Proof of principle research on earlier versions of nonlinear interface switches, along with the general concepts outlined in the Final Report for Task P-9-6008, serves as an adequate introduction to the theory and strategy of testing the tungsten oxide thin films. As a part of this effort, we developed a Fresnel coefficient formalism for evaluating the indices of refraction of the laser deposited films which comprise the switches. This enables us to evaluate the photorefractive properties of the films as well as their static optical and electrical properties. These aspects of the effort, which bear on the question of how these switches may be improved, will be covered below after a Procedure section.

Procedure

The materials fabrication[1,2] and operational aspects of the switches[3] will be described in detail in a separate section below. For our immediate intention of detailing the progress in setting up general switch evaluation hardware and software, we note that switch evaluation was accomplished utilizing two basic approaches. In the first, the net reflectivity of a switch was measured at a single laser power over a range of angles of incidence. This allowed determination of the angles of incidence over which a switch could potentially be evaluated in a NAND, OR or AND mode. Given the choice of angle of incidence, then the evaluation took the form of determining the reflectivity as a function of laser power. If the index of refraction of any part of the switch is a function of laser power, i.e. is photorefractive, then the reflectivity will be a function of laser power. Detecting this effect is the essence of switch evaluation for this type of switch using pulse trains. It should be emphasized that we employed this approach only as a prelude to use of single pulses in a pump-probe configuration.

A very brief description of the switching mechanism is in order at this point. The basic idea is that whenever light encounters a boundary while traversing a region filled with two media having different indices of refraction, part of the light is reflected and the other part is transmitted. The proportion of the incident light which is reflected from the interface is proportional to the difference between the two indices.This is in perfect analogy with what happens when an electronic signal encounters an impedance mismatch while traveling between discrete electronic devices. Figures 1a and 1b suggest this situation. If the film material is sufficiently photorefractive, then it's index of refraction is a strong function of the optical power incident on it. The proportion of the incident light reflected is thus a function of the amount of light which is incident upon it. As will be discussed in greater detail later, this is the basis of all switching action for this kind of device.

For a planar substrate, one can measure switching behavior by monitoring either the optical power transmitted across the boundary or the amount of light which is reflected. Any deviation of either of these optical powers from linearity, when plotted as a function of the incident power, is a function of the degree to which either the film or substrate's index of refraction is a function of the incident power. The use of the prism substrate was suggested by the proof of principle research and can be simply explained as follows. Whenever light encounters an interface between one medium which has a greater index of refraction and another medium which has a lesser index of refraction, there will be a critical angle (see Figure 1b angle C) for which all the light traversing the interface will not be able to reenter the interface. The dependence of the reflectivity of the interface near the critical angle is a very steep function of angle and so reduces the amount of photorefractive behavior needed to observe switching. In addition, the incident and reflected light, with respect to the prism-film interface, are separated from each other automatically. We will return to a discussion of switching and device fabrication in a later section.

A software program called ASYST, which we describe software so as to serve as a primer for future users, has been used to control and record data from various laboratory equipment with a single personal computer.

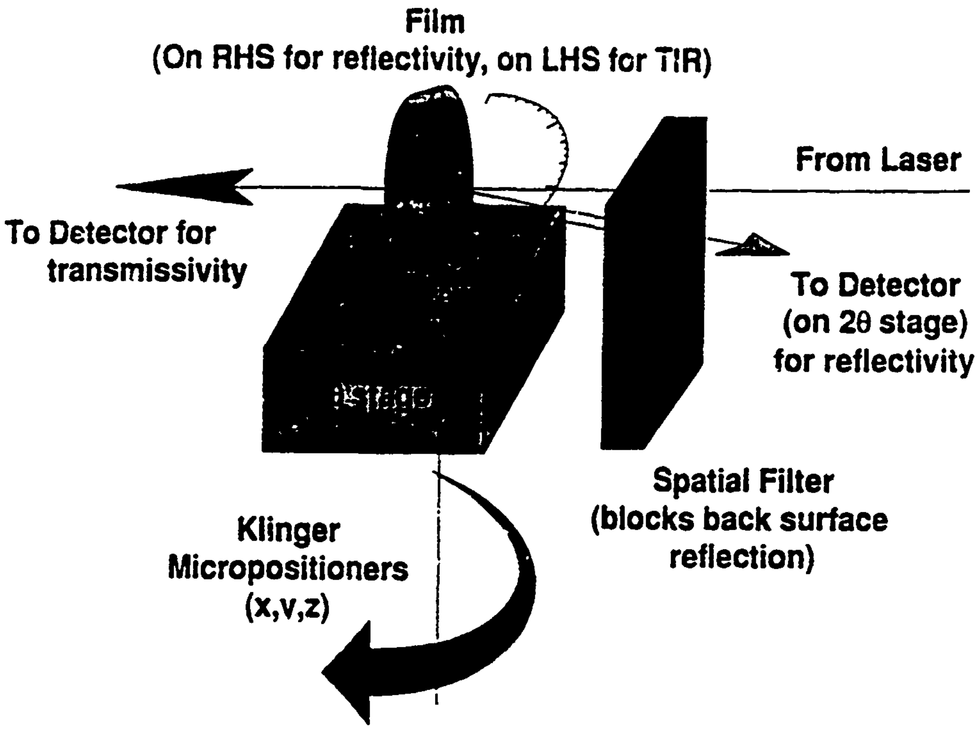
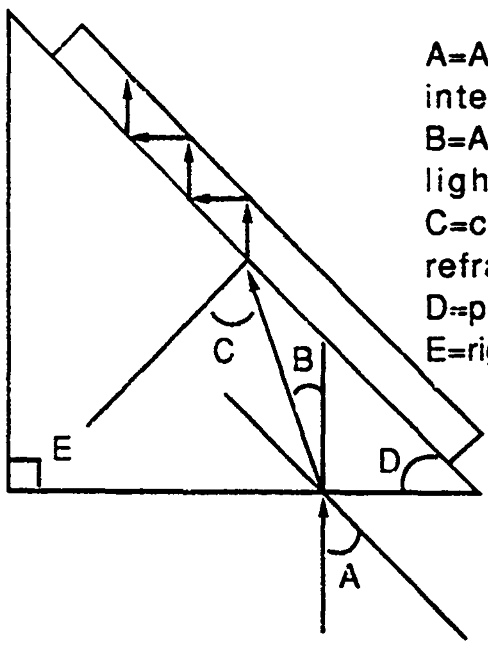


Figure 1a(above). test configuration for films on planar substrates
Figure 1b(below). test configuration for films on prisms



A=Angle of incidence prism-air interface
B=Angle of refraction for incident light
C=critical angle for total internal refraction(TIR)
D=prism angle
E=right angle=D+B

Words in bold and italic print are commands or variables that need special attention, while words in bold, italic, and underlined are DOS file names. A large portion of this publication discusses topics covered in the manuals of ASYST, a software package currently being used at the Air Force Photonics Center. To better understand the software program, you may want to refer to the manual while reading this publication. Braces, {}, are used to cite the manual and page number. The letter I represents the Module I Tutorial (System, Graphics, Statistics) and the letter N represents the additional manual ASYST 3.10: Your Guide to ASYST's New Feature Enhancements.

In order for a lab device to talk to a personal computer the device must have an interface, usually either a RS232 or IEEE-488 interconnect. Because RS232 can be rather difficult to use we have used the IEEE-488 interconnect whenever possible. The IEEE-488 port is connected to a personal computer through an interlink called GPIB (General Purpose Interface Bus). BASIC and C programming languages can control the GPIB system, but the programs would be long and tedious. The ASYST programming language offers GPIB and RS232 control with graphics display, Lotus 1-2-3 compatibility, and data plotting. ASYST has more commands than higher level languages such as BASIC with the ability to create user defined command words to execute many ASYST commands with one user defined word. ASYST can be easier to use, but like all programming languages it takes time to learn.

GPIB DEVICE MAIN MENU

DATE: 03/13/92

KLINGER STEPPING MOTORS	MENU CONFIGURATIONS
LASER BEAM ANALYZER	EXIT TO THE 'OK' PROMPT
LASER POWER CONTROLLER	EXIT TO DOS
NON-LINEAR OPTICAL SWITCH TEST	

USAF PHOTONICS CENTER
GRIFFIS AIR FORCE BASE
ROME, NEW YORK

by Brian DePaul

Figure 2. Main menu for device automation

DATA ACQUISITION FOR OPTICAL SWITCHES:

OPTICAL SWITCH TEST SETUP

Using a mode-locked argon ion laser, the beam is first polarized and sent through a Laser Power Controller (LPC). A beam-splitter then splits the laser beam into two separate beams of unequal intensity. Mirrors redirect the two beams to become nearly parallel and close together before entering a light shielded box. Upon enter the box the beams reflect and refract from the surface of the film and the substrate. The reflected beams are measured by a photodetector connected to a power meter. See Appendix - A for a diagram of the laboratory.

ENVIRONMENTAL CONSIDERATIONS

Stray light from the laser beam reflected off various objects in the laboratory caused unwanted intensities to be recorded. Emissions from computer monitors and light from the outside hallway also affected our readings. To keep this unwanted light from reaching the detector a light shielding box was constructed. A longer focal length lens replaced the previous lens to allow the lens and mirrors to be outside of the box. A black cylinder, placed where the two parallel beams enter the box, help block stray light from entering the box. As we increased the beam intensity there were only three light sources left to eliminate. One source was a reflection from one of the two beams at the focusing lens. This reflection angled above the substrate and reflected off the micrometers holding the substrate. Black tape was then used to cover the micrometers and minimize this reflection. The other sources were made when the beams contacted the surface of the substrate and the beams were split into reflected and refracted beams. The refracted beams continued through the substrate until contacting the other side of the substrate. At the other side of the substrate the two refracted beams were split into reflected and refracted beams. The reflected beams travelled back through the substrate and toward the detector. These second reflections were at a small distance from the first reflections and were blocked by a black spatial filter which had one hole to allow the first reflections through to the detector to be measured. The third source was the light from the beams refracted through the substrate. This source reflected off the black wall of the box. This source was the most intense of the three sources of unwanted photons. To minimize its reflectance, a block of black razor blades was put at the site of reflection. Sporadic movement and vibrations of any of the devices, mirrors, and the argon laser are countered by a floating optics table.

TEST INSTRUMENTATION

Cambridge Research Institute - Laser Power Controller

A laser power controller offers the ability to change the output power of the laser beam without changing any of the parameters of the laser itself. This device is also controllable over a GPIB bus to allow the computer to change the output level and take test measurements. Although the laser power controller has a dip switch to change its GPIB address, the dip switch is inside the controller. I have used its factory set address of 8 to avoid disassembly of the controller. The other devices I have used either have factory settings other than 8, or are easily changed.

Hewlett Packard - HP8116A Signal Generator:

The Signal generator is an easy device to communicate with and is helpful in programming for an oscilloscope, but has not yet played a part in our experiments. However, if we ever need to use it we'll have a program ready to help us in the lab. Like most GPIB ready devices, the GPIB address is defined by a dip switch on the back panel of the device.

Ithaco - 385EO Lock-in Amplifier System:

Although our experiment hasn't yet called for a lock-in amplifier, another experiment we are currently conducting does need the use of a lock-in amplifier. The Ithaco does some calculating of data for you, but it is only accessible through the GPIB bus. The front panel of the lock-in amplifier limits it's use, but a computer can alter more parameters and offer better control over the device. The GPIB address is located on the back panel of the 385EO which is an option device for the lock-in amplifier.

Klinger - MC4/MD4 Stepping Motors:

The Klinger controls various motorized stages for different laboratory needs. Two rotational stages control the rotational angle of the substrate and the detector. Two linear stages in the X and Y directions are used to align the film directly over the center of rotation of the two rotational stages. A Klinger stepping motor has also been used to control the height of all of stages in the Z direction. The GPIB address for the motors is on the back of the Klinger motor controller. It is an easily changed dip switch setting.

Newport - 835 Optical Power Meter:

When the Spiricon camera system became temporarily inoperable, a power meter replaced the Spiricon LBA to measure the total power. An attenuator was attached to the power meter to measure power above 2 milliwatts when the laser's power was increased for higher intensity measurements reflected from the substrate. The GPIB address is set once again by a dip switch on the back panel. However, this dip switch includes an option for talk/listen and talk only. The talk only option can be found at dip switch number 6. This allows for the device to continuously send data into the GPIB bus.

Spiricon - LBA-100 Laser Beam Analyzer:

The laser beam analyzer uses a camera to show the intensity of the beam across a square area. The analyzer measures both total and peak power in Watts, Joules, or relative power. A screen plot is made from the data collected in the camera with various colors representing different intensity ranges. The GPIB address for the laser beam analyzer is driven through it's own internal software. The address can easily be changed or viewed by using the Spiricon's menu system.

ASYST PROGRAMMING

The control program is written in a commercial software language, ASYST, that uses special memory areas called stacks to perform its operations. The number stack manipulates numeric scalar and array variables, while the symbol stack is used for character string, true or false, and menu operations. The stacks use the variables on a last in, first out basis. ASYST also operates in polish notation. That is to say that the variables are placed before the operand instead of between them. Normally we would use 2 * 4 + 3, in polish notation it would be 2 4 * 3 +.

ASYST Configuration

Although it can be first run with ***ASYST.COM***, other .com files can later be made to run ASYST. To change its configurations press F2 at the OK prompt in ASYST after executing the .com file. This will bring up the Configuration Menu *[I:1-16]*. The programming that has been done in ASYST has centered around communicating with laboratory devices using GPIB, let us now take a moment to discuss the GPIB board. The majority of GPIB boards being used at this facility are manufactured by National Instruments. The GPIB boards we currently have require configuration before they can be used.

GPIB Board Configuration with IBCONF

In order to use GPIB with ASYST or any other program, the GPIB board must first be configured before entering ASYST. For National Instruments a program called ***IBCONF*** is used to set parameters for the board and all the devices connected to it. For ASYST you will need to know the address of each of the devices on the board and each individual End Of String (EOS) character. If a device is not configured in IBCONF you may configure the board by reading the device manual for GPIB communication. Some devices have preset GPIB addresses that can not be changed, while others have dip switches to change their factory presets. Once you know the address, use IBCONF to set EOS characters (in Hex), timeout setting, interrupt setting, and the base I/O address. The GPIB board's manual should give the factory preset interrupts and I/O addresses (Figure 3). If the interrupt or I/O addresses are not available due to other programs already using them, then you will need to locate open interrupts or I/O addresses using DOS or a personal computer utility programs such as Winsleuth or Quarterdeck Manifest. Ensure that all of the devices you intend to use are currently connected to the board with GPIB device cables. In IBCONF make sure that lines are drawn to connect GPIB0 (Figure 4). Software connection is made with function key F4. Save your configuration and reboot the computer to put these changes into effect. Remember your device addresses and EOS characters for configuration in ASYST.

```
National Instruments    Board Characteristics            IBM PC-AT
Board: GPIB0                               SELECT (use right/left arrow keys):

Primary GPIB Address ......... 0           0 to 30
Secondary GPIB Address ........ NONE
Timeout setting ............... T3s
EOS byte ...................... 10H
Terminate Read on EOS ......... yes
Set EOI with EOS on Write ..... yes
Type of compare on EOS ........ 7-bit
Set EOI w/last byte of Write .. yes
GPIB-PC Model ................. PC2A
Board is System Controller .... yes
Local Lockout on all devices .. yes
Disable Auto Serial Polling ... yes
Disable Device Unaddressing ... no
High-speed timing ............. no
Interrupt jumper setting ...... 7
Base I/O Address .............. 02E1H
DMA channel ................... 1
Internal Clock Freq (in MHz) .. 6

F1: Help      F2: Explain Field      F6: Reset Value      F9: Return to Map
```

Figure 3. National Instruments IBCONF.COM Controller Settings

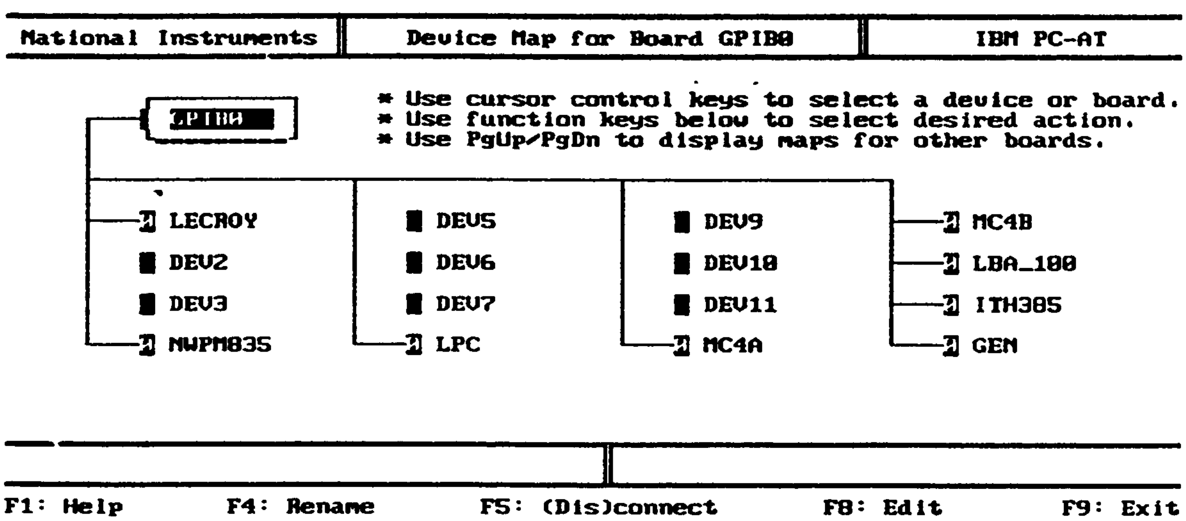


Figure 4. National Instruments IBCONF.COM, GPIB - PC II

ASYST Hardware Specifications:

At the ASYST configuration menu first select hardware configuration (Figure 5). ASYST is originally set up for a slow computer with monochrome monitor and IBM printer. Change the selections in the Hardware Configuration first so that you may make use of the selections when continuing the configuration process *[I:1-18]*. For instance, you cannot edit the color of the ASYST prompts unless your software is configured for a color monitor.

```
Configure            Current

CPU Type             CPU Type is 80286 or 80836
CPU Speed            CPU Speed is 16.00 MHz
Display              IBM Color Graphics Card, Black/White Monitor
Printer              IBM Graphics Printer
                        (for 200 vertical pixel display mode)

                         Active Keys

    <Enter>:        Select menu item or accept parameter for prompt
    <UpArrow>:      Move to previous menu item or prompt
    <DownArrow>:    Move to next menu item or prompt
    <LeftArrow>:    Move to menu item or prompt to the left
    <RightArrow>:   Move to menu item or prompt to the right
    <Home>:         Move to the first menu item or prompt
    <End>:          Move to the last menu item or prompt
    <Esc>:          Exit current menu or prompt list
```

Figure 5. ASYST Hardware Configuration Menu

Selecting ASYST Overlays:

ASYST has many sets of command words for different functions. Select only the overlays of command words for the functions that you will need (Figure 6). These overlays take up plenty of memory, so don't load overlays you will not use! If you are going to use the GPIB system you must load GPIB master and the overlay for your particular GPIB board *[I:1-16]*. Each of the driver overlays contains commands for more than one GPIB board. Choose only the driver overlay that contains your computer's GPIB board. For a list of supported GPIB boards and the driver overlays refer to Module 4 GPIB/IEEE-488 Appendix D of the ASYST manuals. The Help Overlay doesn't offer much help for the memory it takes up and I suggest not loading this

GPIB Device Configuration

Each GPIB device to be utilized by ASYST must be assigned. The program needs to know the EOS characters, I/O addresses, their user defined names, and whether the EOS characters are on or off. Next you'll need to initialize the GPIB bus. Initializing the bus takes three ASYST commands which I have shortened to one called ***init*** (see Appendix C - Short Commands). Since the GPIB board I was recently working with allows only 16 devices I created a text file called ***GPIB3.XXX*** to assign all of the devices with their EOS character, address, and name (Appendix D - GPIB Device Configurations). This text file is automatically loaded by my main text file program and allows the GPIB Device Configuration file to be edited from an option given in the main menu.

Making Menus

In the latest version of ASYST, menu command words were added to create user defined menus for other users unfamiliar with the program *[N:3-1]*. Menus are subprograms of special command words. These exclusive menu commands are used only inside a menu definition. The menu is first

```
HP8116A.MENU
    MENU.STATUS HP8116A.STATUS
    MENU.BLOW.UP
    1 1 24.79 MENU.SHAPE
    C5B C5F MENU.COLOR
    C5P MENU.PROMPT.COLOR
    1 1 " CHANGE PARAMETERS" MENU.ITEM( SGCP.MENU )
    3 1 " EXECUTE DESIGNED PROGRAMS" MENU.ITEM( SGDP.MENU )
    5 1 " ENABLE / DISABLE FRONT PANEL" MENU.ITEM( LOCK.OUT.SWITCH )
MENU.END
```

Figure 8. Example of a Menu Definition

declared using the command menu followed by the name of the menu to be defined. The menu definition begins with the name of the menu. The menu definition terminates when the menu reaches the menu command ***Menu.End*** (Figure 8). A menu is basically a text window with executable items for the user to choose from. The size and location of the menu is determined by the command ***Menu.Shape*** . Any predefined colon definitions, overlay commands, basic ASYST commands or other menus are executable in the menu by using the command word ***Menu.Item***. This command also defines the location and text to be displayed as a menu option. Excluding the menu title and menu selections all other text can be displayed by a user defined colon definition executed by the menu command called ***Menu.Status***. For GPIB device menus this command can be used to display current data from the device such as signal generator parameters in the program ***HP8116A.xxx*** (Figure 9).

```
: HP8116A.STATUS     12 FOREGROUND
   DISPLAY.DATA      13 FOREGROUND
   26 8 GOTO.XY ." CURRENT PARAMETER SETTINGS"
   0 8 GOTO.XY ." ********************"
   58 8 GOTO.XY ." ********************"
   1 10 GOTO.XY ." Amplitude:"       40 10 GOTO.XY ." Output Disabled:"
   1 11 GOTO.XY ." Offset:"          40 11 GOTO.XY ." Autovernier:"
   1 12 GOTO.XY ." Operating Mode:"  40 12 GOTO.XY ." High Level"
   1 13 GOTO.XY ." Control Mode:"    40 13 GOTO.XY ." Low Level:"
   1 14 GOTO.XY ." Trigger Slope:"   40 14 GOTO.XY ." Burst Number:"
   1 15 GOTO.XY ." Haversine(-90):"  40 15 GOTO.XY ." Repetition Rate:"
   1 16 GOTO.XY ." Waveform:"        40 16 GOTO.XY ." Sweep Start Freq:"
   1 17 GOTO.XY ." Frequency:"       40 17 GOTO.XY ." Sweep Stop Freq:"
   1 18 GOTO.XY ." Duty Cycle:"      40 18 GOTO.XY ." Sweep Marker Freq:"
   1 19 GOTO.XY ." Width:"           40 19 GOTO.XY ." Sweep Time:"
   1 20 GOTO.XY ." Limit (on/off):"  40 20 GOTO.XY ." Complement (on/off):"
   11 FOREGROUND  ;
```

Figure 9. Menu.Status example from HP8116A.XXX

As a special note the menu commands look decent in normal display, but appear slightly worse in graphics display mode.

Arrays and Tokens

ASYST arrays are very similar to arrays in any other programming languages *[I:5-1]*. They can have multiple dimensions and can be accessed one element at a time. These arrays can also be accessed one dimension at a time or you can change the entire array all at once by using the array name the same as you would a scalar variable name *[I:18-1]*. To access one dimension at a time you can use the *!* character as a wildcard variable with the ASYST command ***XSECT*** directly in front of the accessing braces (ex. ***XSECT [2 , ! , 5]***). This creates a cross sectional view of the array. If a portion of a dimension is what you desire use the command ***Sub*** in front of the braces. However, you cannot use the *!* character in a ***Sub*** command. ASYST also offers string arrays that are limited to two dimensions with one of the dimensions being the maximum character length of a string. Because ASYST does not automatically make use of expanded memory, tokens become an important tool for users to make use of a 286, 386, or 486 with expanded memory. Tokens are defined by taking the data and size of an already existing array. In the ASYST memory configuration, memory is allocated for unnamed arrays as well as a token heap. If you are using expanded memory the token heap size will not make a difference in your programming, but the size of the unnamed array heap can limit the maximum size of your arrays and your tokens. It would be more beneficial for users with expanded memory to increase the unnamed array memory allocation by decreasing the named array memory. This will allow for larger sized tokens in expanded memory. Keep in mind that when you enter a saved program from DOS all arrays are blank and your tokens have no size, data or place in expanded memory. You will then have reload tokens into expanded memory, define their size and load them with any necessary data.

Data files

While ASYST has its own data file system, you can save data in a LOTUS 1-2-3 spreadsheet format (Figure 10), ASCII text file or into a BASIC data file. First let us discuss the ASYST data filing technique *[I:17-1]*. ASYST uses what it calls a file template to map out the structure of each data file. Data files contain only numeric arrays and comment statements. If you wish to store strings, you would need to use the comments. Keep in mind that comment statements have a maximum length of 64 characters. If you need to store strings of greater length, I suggest you convert your string arrays into integer arrays to be properly stored. This also means that upon restoring data you will have to convert the data from an integer array back into a string array. Once a file template is made it can not be changed with the exception of appending an array to the end of the file. If you desire to change the size of an array in the data file you must recreate the entire data file. The LOTUS 1-2-3 interface doesn't need a file template *[I:17-23]*, but you must carefully decide which direction to write an array into a spreadsheet. Keep in mind there is only one array written to a spreadsheet at one time. If you want to write more than one string or numeric array, you must reset a pointer using 123WRITE.DOWN and 123WRITE.ACROSS. Data can be read from ASCII and DIF format files into ASYST strings, but ASYST does not let you write to BASIC or DIF files interactively *[I:17-19]*. ASYST does offer a way to direct output to files to create ASCII text files. You can then edit these files by the ASYST text editor or any word processor.

```
: S123
   TOTAL      DATA123 XSECT[ ! , 1 ] :=
   DEGREES    DATA123 XSECT[ ! , 2 ] :=
   DATA123 SUB[ 1 , Q ; 1 , 2 ] EQUIV> DATA.123
   SAVE.RESTORE.MENU MENU.EXECUTE          \
   FILE.PATH " \" "CAT                     \
   NAME.FILE "CAT FILE.NAME ":=            \
   FILE.NAME DEFER> 123FILE.CREATE         \
   FILE.NAME DEFER> 123FILE.OPEN           \
   1 1 123WRITE.ACROSS                     \
   1 1 Q 2 123READ.RANGE                   \
   DATA.123 ARRAY>123FILE                  \
   123FILE.CLOSE  MENU.ESCAPE MENU.ESCAPE ;
```

Figure 10. Example of LOTUS 1-2-3 interface commands

Loops

As with any respectable programming language, ASYST offers loops to better organize tedious and repetitive portions of a program. ASYST DO loops have scalar variable counters that are useful in keeping track of where you are inside of a loop or nested loop *[I:16-2]*. I mention these counters because I have found them extremely useful in any programming language. The array manipulation and other various mathematical processes performed inside the loop require at times a counter. Here ASYST offers a counter without having to program the old method of ' N = N + 1 '. These counters, beginning with 'I' for the innermost loop, should not be redefined in a user defined program. In other words it is not advisable to create a variable or colon definition with a name of I, J, or K. If you view my programs you may notice that I use loops frequently to save room in the program file (Figure 11), neatly organize command lines, and best of all increase the speed of loading the program. ASYST offers indefinite loops for those of you who do not know the exact count on which to end *[I:16-9]*. These loops, BEGIN-UNTIL and BEGIN-WHILE-REPEAT, will continue until there is a false condition present in front of the UNTIL or WHILE commands. Although I have not yet had the opportunity to use this type of loop, I have mentioned it for future reference if you are in need of looping until a certain condition is met.

```
121 1 DO          \  X DIRECTION        REPLOT LBA LASER PROFILE
 121 1 DO         \  Y DIRECTION         PIXEL BY PIXEL (120 X 120)
     DATA2 [ J , I ] COLOR
    I 2 * 396 + M := M 1 + Y :=
    J 2 * L :=
    348 L - N := N 1 - Z :=
    M N P!  M Z P!
     Y N P!  Y Z P!
 LOOP
LOOP
```

Figure 11. Example of a DO LOOP from Appendix K - LBA

SPECIFIC DEVICE AUTOMATION

Cambridge Research Institute - Laser Power Controller

CRI offers their laser power controller with different options built into it. It a helpful note is to make sure which type you are using in order to correctly program for the specific parameters it has. We are using a model that can change the percent power or keep the transmissibility at a specified amount. Our experiment calls for the control of the output power. Control of the device can be difficult at times with an erratic laser beam. If you try to specify a power level where the percent amount of transmission can peak at times over 100%, than the controller will be in error and leave the power level at its present state. Ensure that when you wish to communicate with the controller that a laser beam is present. If the laser beam isn't going through the controller your communication will cause a system crash and you will need to restart the ASYST program by using ***Control-Break***.

Hewlett Packard - HP8116A Signal Generator

Although communicating with the signal generator can be simple, the number of different parameters adds length to my program. The basic use for the program is to save particular parameter settings to be restored at later dates quickly and easily.

Ithaco - Lock-in Amplifier

The most difficult part of programming for the lock-in amplifier was figuring out the data format. Ithaco sends a numeric code that describes the output data. The data may come in 64 different combinations of 7 formats. Displaying which formats are currently being used is cumbersome to say the least. I had to make sure that if all formats were being used the length of display wasn't longer than the length of available screen space. This makes displaying the data itself rather arduous. I had to limit the amount of data to 10 different sets at a time.

Klinger - Stepping Motors

The Klinger stepping motors are an essential part of our experimental setup. My ASYST programming allows easier control over the stepping motors. My program displays the counters of the four axes of one controller, and offers moving a motor to a specified count. I have made changing the stepping rate or speed of the motor more accessible than through the front panel of the controller. In my program I was faced with the problem of inputting a letter designating a particular controller and changing it to an integer such as A-1, B-2, C-3, etc. Inside my colon definition for ***CHOOSE.CONTROLLER*** the user inputs a letter and ***"UPPER*** insures that the letter is capitalized. I then change the ASCII letter to it's numeric counterpart. Since the upper case ASCII characters start at 65, I then subtract 64 from the decimal character. Now an 'A' will be seen as 1 and a 'B' as 2 and so on. The useful note to make here is that for some reason unknown to me, ASYST would not correctly recognize the letter directly following an input statement. This causes a slight problem, but I was able to work out a simple solution. After the input statement the letter is saved into a variable, ***KD***. I tried to take the ASCII value of the variable KD, but I would always be returned with the ASCII value of K. In order to get around this irritating snag I put the ASCII command and my variable ***KD*** into a string. I then used ***"EXEC*** to execute the commands inside the string, and it worked.

Newport - Power Meter

The power meter was the easiest device to program. Our experiment just needed to record the reading from the meter. The Newport model offers talk / listen or talk only mode. I placed the meter in talk only mode so that it continuously sends out it's current reading out into the GPIB bus. Whenever I need a power reading I can execute a GPIB Read from ASYST into string variable. Because of the small amount of programming for this device, I did not make a separate sub program devoted to it. To date you can find it's use in the 'Joe' program for the Non-Linear Optics testing.

Spiricon - Laser Beam Analyzer

The difficult task in programming for this device is the large amount of string space needed to transmit the profile from the analyzer into the ASYST program. The profile is an array of 120 x 120 pixels with a measured intensity between 1 and 255. This means a string of over 14,400 bytes long. Make sure you have the available memory before considering to download the laser beam profile. Reproducing the profile is even more difficult. The only known way to reproduce the profile is pixel by pixel. Although it can be easily programmed, the display routine is rather slow. I have also had trouble with sending the profile back to the analyzer. To date I have not yet succeeded. The laser beam analyzer is great by itself, but communicating with an IBM PC can be troublesome.

NON-LINEAR OPTICAL SWITCH TEST PROGRAM

Up to this point I have discussed some of the basic elements of my GPIB device programs. Another program has been written that incorporates most of these device programs to operate our optical switch testing. This program centers around a nested loop. First data is recorded from either the laser beam analyzer or the power meter and then the Klinger rotational stages are moved to another angle. An option has recently been added to allow the program to collect data and then change the power of the laser beam. With this option the rotational stages remain at their current position. The program started out to be simple, but it has quickly grown to accommodate different testing methods. For instance, the program now can collect data for a range of angles, automatically save the data, change the Z axis, and repeat the procedure (Figure 12). Changing the Z axis lets us collect data from a different location on the optical switch. Outside of this nested loop the user can quickly change the angular position of the substrate, change the power of the laser beam, view a graph of the latest collected data, and save the data in different formats.

```
: MOVE.SETUP           \ This routine calculates the current substrate angle
  MC4A " DW" GW        \  from the counters of the two rotational stages,
  D.W GR D.W 3 20 "SUB 0 "NUMBER V :=  SS.CLEAR   \ then calculates the
  MC4B " DZ" GW                                   \ needed positions for a
  D.W GR D.W 3 20 "SUB 0 "NUMBER X :=  SS.CLEAR   \ desired angle.
  X 5 * V + 1000 / RX :=                          \  RX = Current angle
                       \ MC4B "z" is the detector and must be positioned at
                       \ an angle twice the size of MC4A "W" (the substrate).
                       \ The MC4B "Z" axis stage is 100 counts per degree
                       \ The MC4A "W" axis stage is 1000 counts per degree
                       \ therefore the count difference is 1/5.

  13 FOREGROUND
  25 21 GOTO.XY ." INPUT THE NUMBER OF DEGREES FOR THE SETUP"
  11 FOREGROUND 7 BACKGROUND
  50 5 GOTO.XY CLRSCR 1 10 "SUB "TYPE
  50 5 GOTO.XY "INPUT SS ":= SS 0 "NUMBER KMD.N := SS.CLEAR

  MC4A     \ Calculate from the previous angle the new position
           \ of the substrate stage.

  RX 2 * KMD.N - 1000 * V := V "." SS ":= " PW" SS "CAT SS ":= SS GW
  MC4B KMD.N RX < IF RX KMD.N := THEN
  KMD.N RX - 200 * U := U "." SS ":= " PZ" SS "CAT SS ":= SS GW
  STACK.CLEAR SS.CLEAR
  13 FOREGROUND  0 BACKGROUND
  25 21 GOTO.XY ." WAIT FOR THIS MESSAGE TO DISAPPEAR         "
  11 FOREGROUND ;
```

Figure 12. Colon Definition from Appendix L - Program: JOE.XXX

Changing the angle of the substrate requires some calculation. The rotational stage holding the detector is located beneath the stages holding the substrate. This means that for every degree that the detector moves, the substrate also moves that same amount. Because we need to measure the reflected beam, the detector must be at an angle twice the angle of the substrate. For a desired substrate angle θ, the detector must move to a position of 2θ. The substrate then must move an angle θ in the negative direction. To accomplish this feat, the current angle is first calculated from the current axis positions. For our setup the "W" axis on the first controller operates the substrate rotational stage. The second controller operates the detector rotational stage on the "Z" axis. To add to the complexity, the rotational stage for the substrate (MC4A "W") moves at a rate of 1000 steps per degree. The detector stage (MC4B "Z") moves at the rate of 100 steps per degree.

After the current angle ***RX*** is calculated, the desired angle is then inputted by the user as ***KMD.N***. The desired position of the stage is calculated from the difference between the previous angle and the desired angle with an adjustment based upon the type of stage.

The rest of the colon definitions are similar to definitions found in the device specific programs. Because I had taken the time to develop programs for each individual device, I can now easily program for combinations of different devices with some of the necessary colon definitions already defined.

AUTOMATED DEVICE CONFIGURATION

As I increase the number of devices on the GPIB bus and in my program, I notice the amount of available program memory quickly decreases. ASYST constricts your conventional memory and tokens can only offer a little help. I have designed a way to easily change which devices are loaded into memory. The program is configured with only the device menus that are needed. The program is then re-saved on to the hard drive with a different name for fast loading from DOS. This keeps devices that are not being used from taking away your precious memory. Whenever my main menu program is initially loaded a menu configuration option is offered. Through this menu you can select the separate menus that you want, or don't want loaded. You can also change the GPIB device characteristics such as name, end of string character code, and GPIB device number. Mouse support is also configured. All of these settings can than be saved under a new name to be opened from DOS. The entire program is reloaded, but the menu configuration option will have been deleted. When you finally leave the current program, you can enter the saved ASYST program with the name that it was saved under. You'll notice that it won't have to take time to load the program, because it was already loaded when it was saved. The menu options will be only those that you had selected earlier. This process makes my programming more versatile to the demands of the laboratory. Although it is easy to use and may not appear to do much, it is extremely complex and hard to program.

SUMMARY

ADVANTAGES TO ASYST

My use of ASYST has centered on its GPIB control. The GPIB bus allows control of different devices from one computer. This makes laboratory control easier. The GPIB bus is manipulated effectively in ASYST. The new menu commands make my programs more user friendly. Designing similar menus in higher level languages would take many hours to program. The menus allow for other people to easily operate our experiment without hours of technical program training. One advantage that I favor is the colon definitions. These definitions are similar to macros, but are easier to create and modify with an ASCII text editor. ASYST also offers statistical analysis, mathematical computations, and graphical analysis that takes time to program in any higher level language.

DISADVANTAGES OF ASYST

ASYST (version 3.1) doesn't make use of expanded memory available in IBM 386 and 486 PCs except in tokens. Tokens help a little, but plenty of conventional memory could be saved for calculations and data manipulation if the entire program was loaded into expanded memory. If more conventional memory was freed the processing time would increase and so would the maximum size of any arrays. I have recently conversed with personnel from the ASYST who assured me that a new version will be coming out soon making better use of expanded memory. Instead of making a DOS window, ASYST makes its own interface. This limits the amount of DOS commands available inside ASYST and some of the commands are used differently. It is usually easier to exit to DOS rather than use the DOS interface commands. Although I was pleased with the ASYST menu commands in the normal display mode, the menu display in graphics mode did not work as well. I'm hopeful that in the next version their problems
will be solved.

FUTURE USE OF ASYST IN OPTICAL SWITCH EVALUATION

Our evaluation setup will be measuring the transmitted and reflected light from the switch with an EG&G Optical Multi-channel Analyzer (OMA) and an Inrad Autocorrelator. The OMA system will analyze the spectrum of the light to include the wavelength. A GPIB connection will be made from the keypad of the EG&G spectrograph. The computer will then control the scanning of the grating inside the spectrograph., which is receiving the transmitted or reflected laser beam. The autocorrelator will then be connected to a LeCroy 9450 Oscilloscope. The oscilloscope will be able to save waveforms, find deviations, full width at half maximum with the background light subtracted, and separate between the two peaks of the split laser beam. The computer will then be connected through GPIB to the Oscilloscope for data extraction and further analysis.

Specific Considerations Regarding Testing of Nonlinear Interface Optical Switches

There are inherent limits in how precisely we can determine the reflectivity versus angle of incidence function. First, the angle of incidence cannot be fixed more precisely than the angular divergence of the laser beam at the point of incidence. In turn, the angular divergence is a function of the focussing used to bring the laser to the switch surface. The greater the desired peak power to be delivered to the switch, the shorter the focal length lens needed and the more imprecisely known the angular divergence. The position of the laser is fixed and the switch must be rotated, as illustrated in Figure1a, through a given angle without moving the irradiated surface in any linear direction with respect to the laser focus.

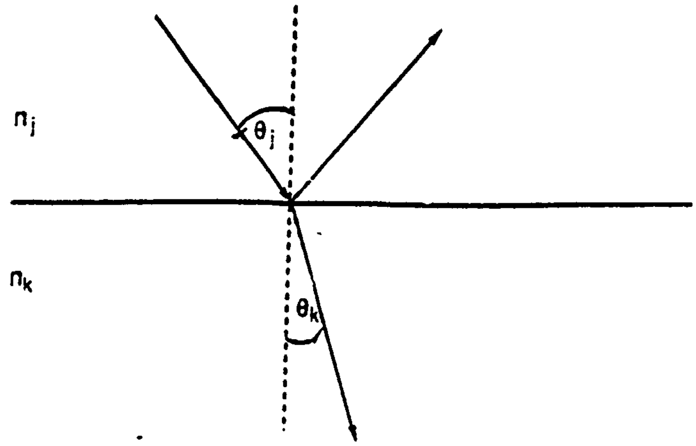
The detectors must move synchronously with respect to the switch because to determine the reflectivity, both the incident power and the reflected power must be measured at each angle. The motion of the switch must be controlled to within several tens of microns to insure, that only one part of the switch surface is probed during the entire evaluation, that the same part of the laser focal volume contacts the switch during the course of the evaluation and that the size of the laser contacted region does not fluctuate beyond that dictated by geometry during the evaluation. Using the notation from the three phase system modelled by Figure 13, this latter requirement involves the fact that as the angle of incidence becomes larger, the region irradiated by the laser smoothly changes from a circle at $\vartheta_1=90°$ to almost a line near $\vartheta_1=0°$. The angular precision is changing throughout as well because the contacted region changes shape continuously. The laser power and polarization must be precisely determined and controlled so that it does not fluctuate during the course of an evaluation. As the degree of focussing of the laser becomes tighter, the tolerances on these parameters only become more less precise. Considering that the intrinsic divergence of our laser pulses is in the range of milliradians to tens of milliradians, and that relatively long focal length lenses, 25cm, were used to focus the light onto the switches, the angular measurements in the results are thought to be precise to $\pm 10^2$ mrad.

Results

Operational and Testing Considerations

The notation used is suggested by the drawings of the experimental arrangement given in Figure 13. The top diagram is for a standard two phase system and the lower drawing is relevant to the three phase system which resembles our switches. Two procedures were used to obtain the

$$R = \frac{I_r}{I_o} = 1 - T = |r|^2 \quad \text{where } r \text{ is the Fresnel Coefficient}$$



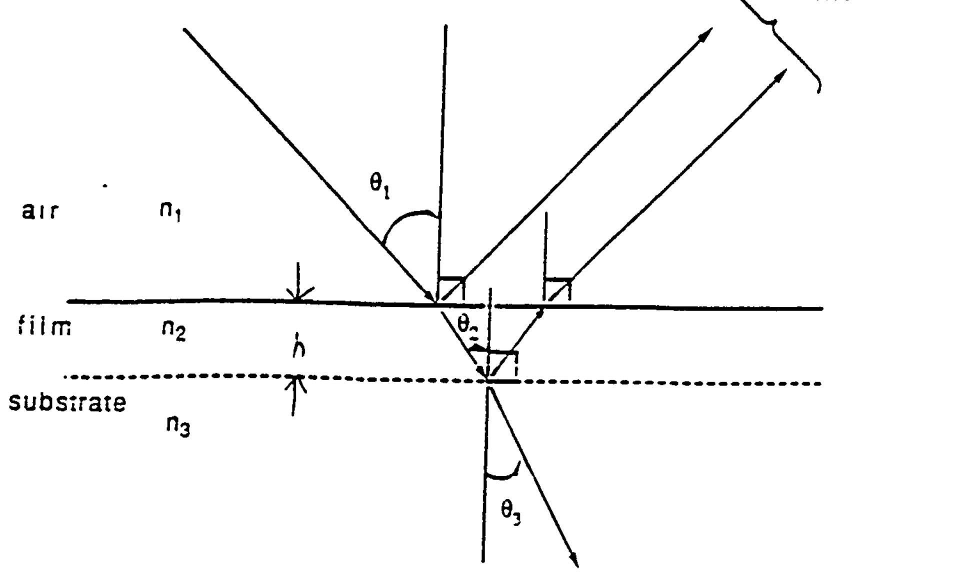
At an interface.

$$R_{//} = |r_{//}|^2$$

$$r_{//jk} = \frac{n_k^2 n_j \cos\theta_j - n_j^2 n_k \cos\theta_k}{n_k^2 n_j \cos\theta_j + n_j^2 n_k \cos\theta_k}$$

There is an angle θ_j, for which $R_{//} = 0$, known as the Brewster angle.

For an air-film-substrate system



$$r_{//} = \frac{r_{//12} + r_{//23}\, e^{-2i\beta}}{1 + r_{//12} r_{//23}\, e^{-2i\beta}} \quad \text{where } \beta = 2\pi h n_2 \cos\theta_2 / \lambda$$

$R_{//} = |r_{//}|^2 \approx R_{12} + R_{23}$ + interference effects (both constructive and destructive)

Figure 13 Two and Three Phase systems as a Basis for Fresnel Equation Model of Switches

Figure 14. Power Dependence of Reflectivity for Planar Substrate Switches

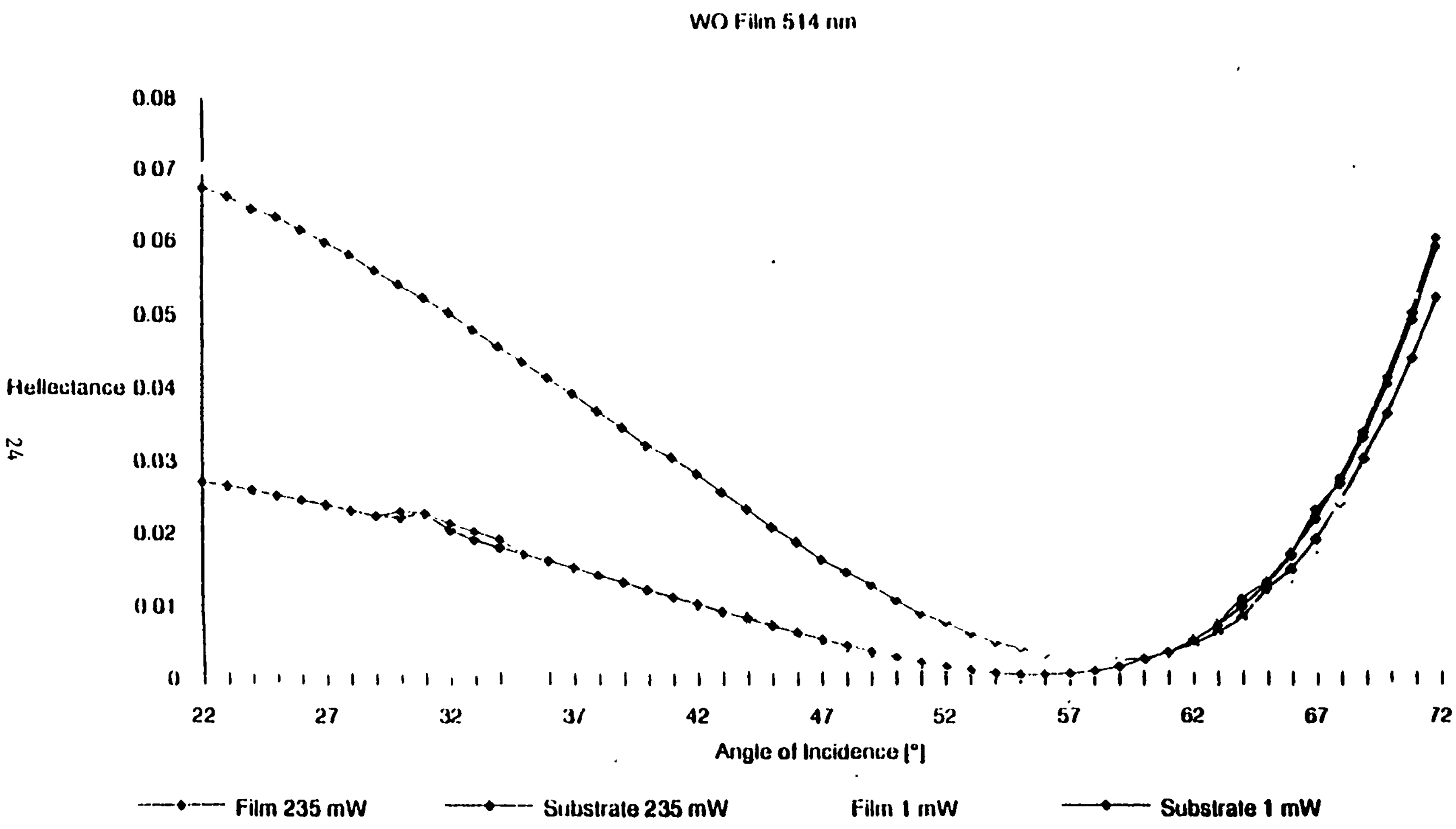


Figure 15. Iteration of Fresnel Equations to Obtain a Range of Reflectance Values.

$x := 1..50$ x is the range variable. MathCad allows a range of 50 for each variable used.

$n2_1 := 2.55$ this is the initial value for the index of refraction of the thin film with an index value that gives us the reflectances we observed from F812RMP2.XLS at 40 degrees incident angle.

$n2_{(x+1)} := n2_x + .001$ this is the incremental step for the index values.

$n1 := 1$ Index of Refraction of first medium (air).

$n3 := 1.489392$ Index of Refraction of third medium (substrate).

$\theta 1 := 68$ Angle of Incidence on the first boundary measured from the normal.

$\theta 1\rho := \theta 1 \cdot \frac{\pi}{180}$ Conversion from degrees to radians.

$\theta 2_x := \operatorname{asin}\left(\frac{n1}{n2_x} \cdot \sin(\theta 1\rho)\right) \cdot \frac{180}{\pi}$ Application of Snell's Law to achieve refracted angle from first boundary

$\theta 2\rho_x := \theta 2_x \cdot \frac{\pi}{180}$ Conversion from degrees to radians.

$\theta 3_x := \operatorname{asin}\left(\frac{n2_x}{n3} \cdot \sin\left(\theta 2\rho_x\right)\right) \cdot \frac{180}{\pi}$ Iteration of Snell's Law once again provides us with the refracted angle from the second boundary.

$\theta 3\rho_x := \theta 3_x \cdot \frac{\pi}{180}$ Conversion from degrees to radians yields

$$r12_x := \frac{\left(n2_x\right)^2 \cdot \cos(\theta 1\rho) - n1 \cdot n2_x \cdot \cos\left(\theta 2\rho_x\right)}{\left(n2_x\right)^2 \cdot \cos(\theta 1\rho) + n1 \cdot n2_x \cdot \cos\left(\theta 2\rho_x\right)}$$

Formula used to calculate the coefficient of reflectivity at the 12 boundary.

$$r23_x := \frac{\left(n2_x\right)^2 \cdot \cos\left(\theta 3\rho_x\right) - n2_x \cdot n3 \cdot \cos\left(\theta 2\rho_x\right)}{\left(n2_x\right)^2 \cdot \cos\left(\theta 3\rho_x\right) + n2_x \cdot n3 \cdot \cos\left(\theta 2\rho_x\right)}$$

Similiar process to obtain c.o.r. at the 23 boundary.

$h := .0000002$ Thickness of thin film.

$\lambda := .000000514$ Wavelength of incident light.

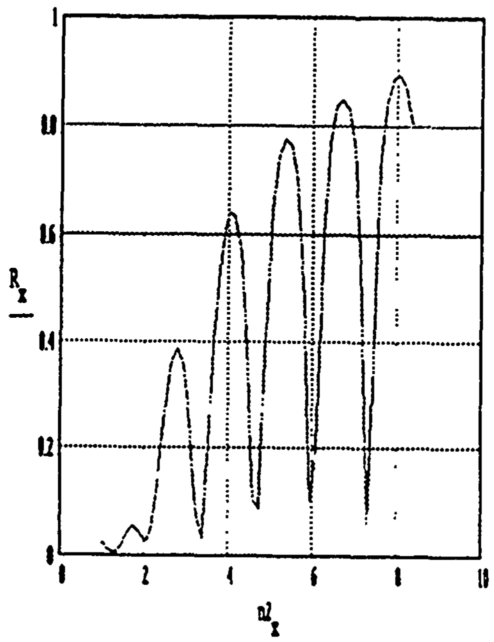
$$B_x := \frac{2 \cdot \pi \cdot h \cdot n2_x \cdot \cos\left(\theta 2\rho_x\right)}{\lambda}$$

$$r_x := \frac{r12_x + r23_x \cdot \exp\left(-2i \cdot B_x\right)}{\left[1 + \left(r12_x \cdot r23_x \cdot \exp\left(-2i \cdot B_x\right)\right)\right]}$$

Complex Coefficient of Reflectivity.

$R_x := \left(\left|r_x\right|\right)^2$ Reflectance

**Fresnel equation Model
using Mathcad**



**Film Index from Fresnel's Equations by ASYST
0520F01.WK1**

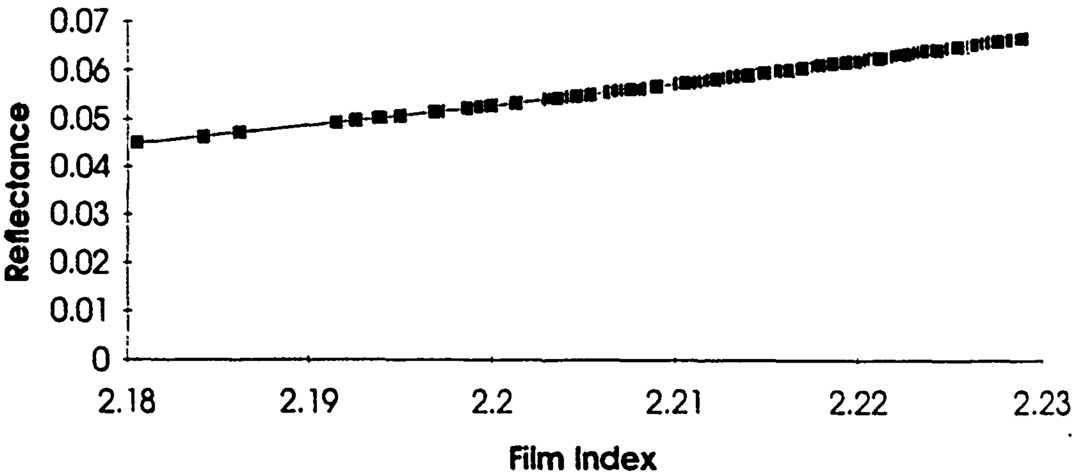
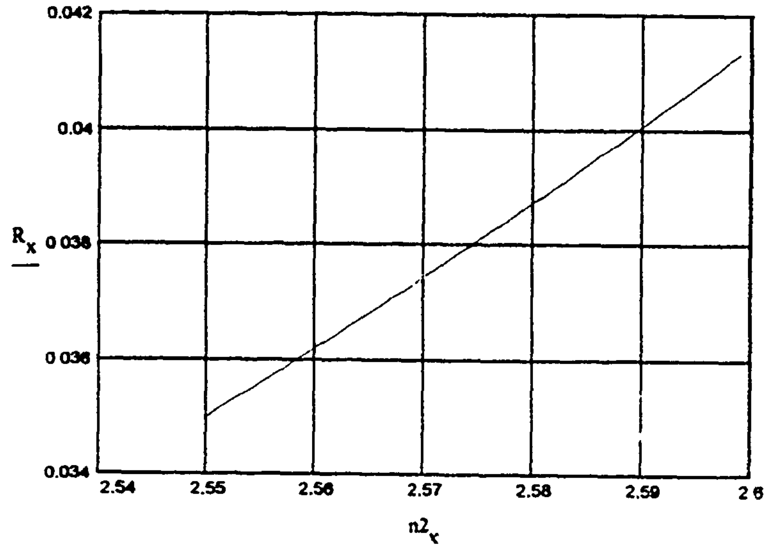


Figure 16. Gross Dependence of Reflectivity on Index of Film

Figure 17. Dependence on Reflectivity on Index at 514 nm

R_x	$n2_x$
0.03500503	2.55
0.03512137	2.551
0.03523829	2.552
0.03535579	2.553
0.03547386	2.554
0.0355925	2.555
0.0357117	2.556
0.03583147	2.557
0.03595181	2.558
0.03607269	2.559
0.03619414	2.56
0.03631613	2.561
0.03643868	2.562
0.03656176	2.563
0.0366854	2.564
0.03680957	2.565
0.03693427	2.566
0.03705951	2.567
0.03718528	2.568
0.03731157	2.569
0.03743838	2.57
0.03756571	2.571
0.03769356	2.572
0.03782192	2.573
0.03795079	2.574
0.03808016	2.575
0.03821003	2.576
0.0383404	2.577
0.03847127	2.578
0.03860262	2.579
0.03873446	2.58
0.03886678	2.581
0.03899958	2.582
0.03913286	2.583
0.0392666	2.584
0.03940081	2.585
0.03953549	2.586
0.03967062	2.587
0.03980621	2.588
0.03994225	2.589
0.04007874	2.59
0.04021567	2.591
0.04035304	2.592
0.04049084	2.593
0.04062907	2.594
0.04076773	2.595
0.04090681	2.596
0.04104631	2.597
0.04118623	2.598
0.04132655	2.599



Plot of Reflectance vs. Index of Refraction at 514 nm

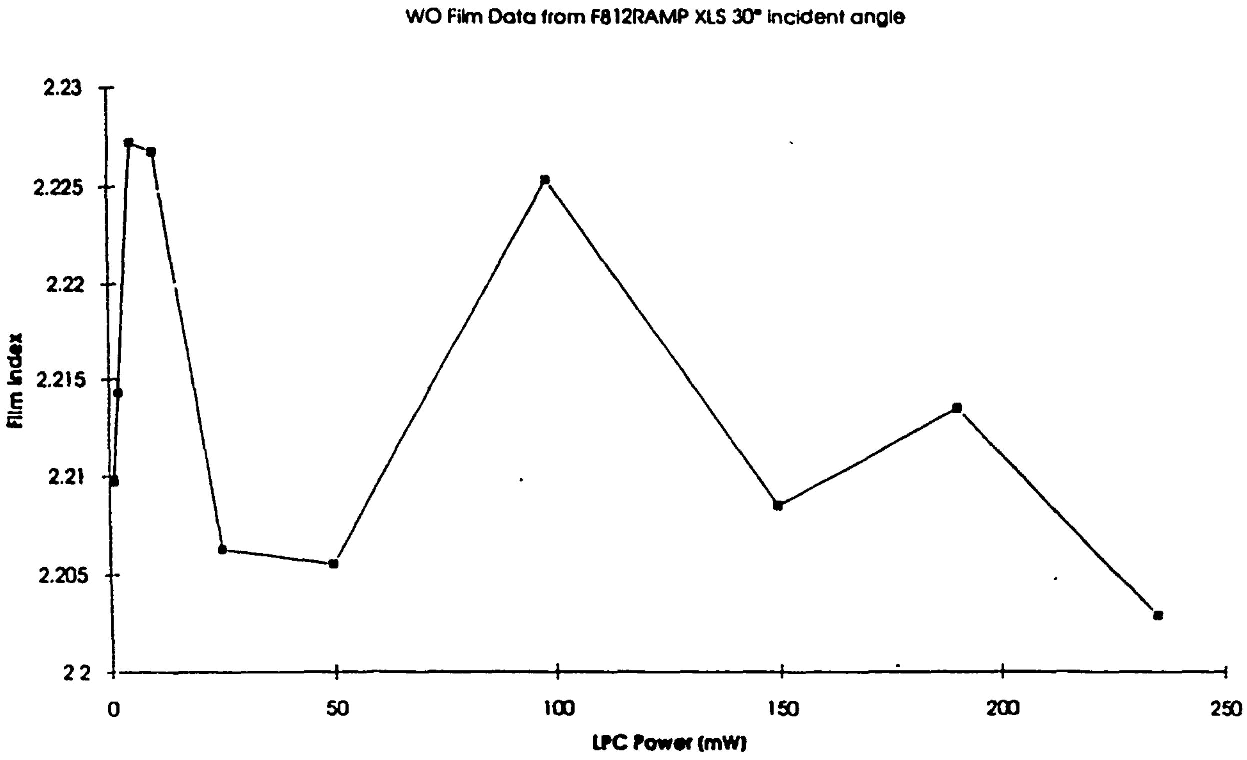
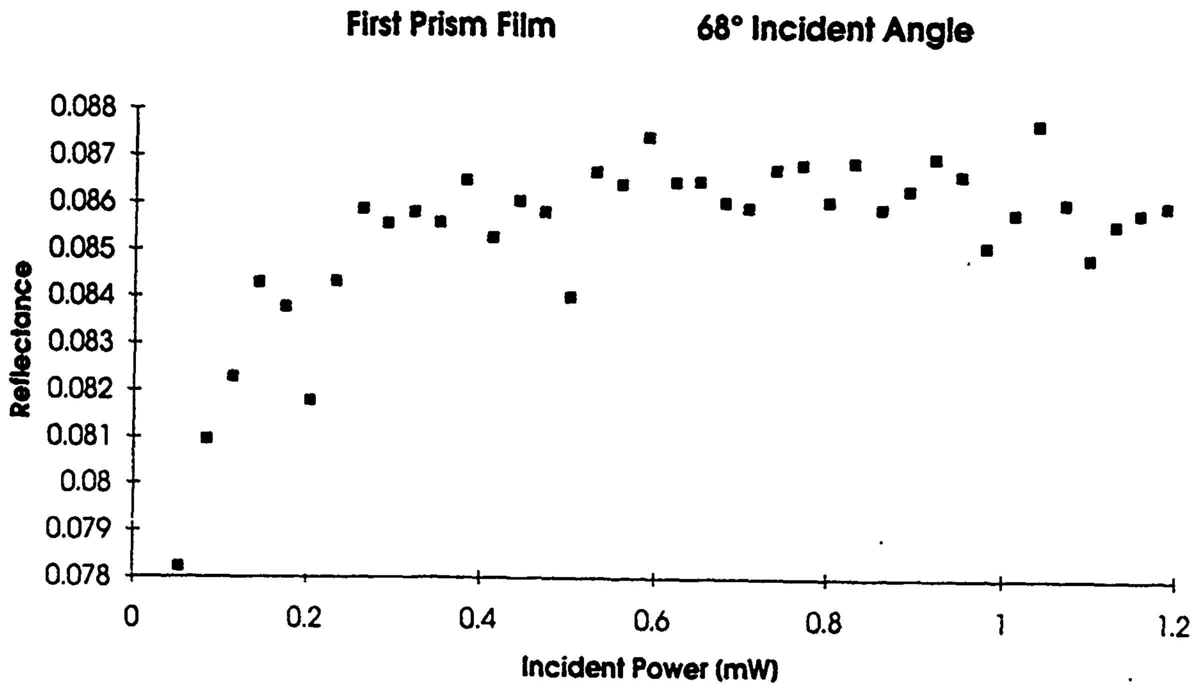


Figure 18. Power Dependence of Index/Planar Substrate



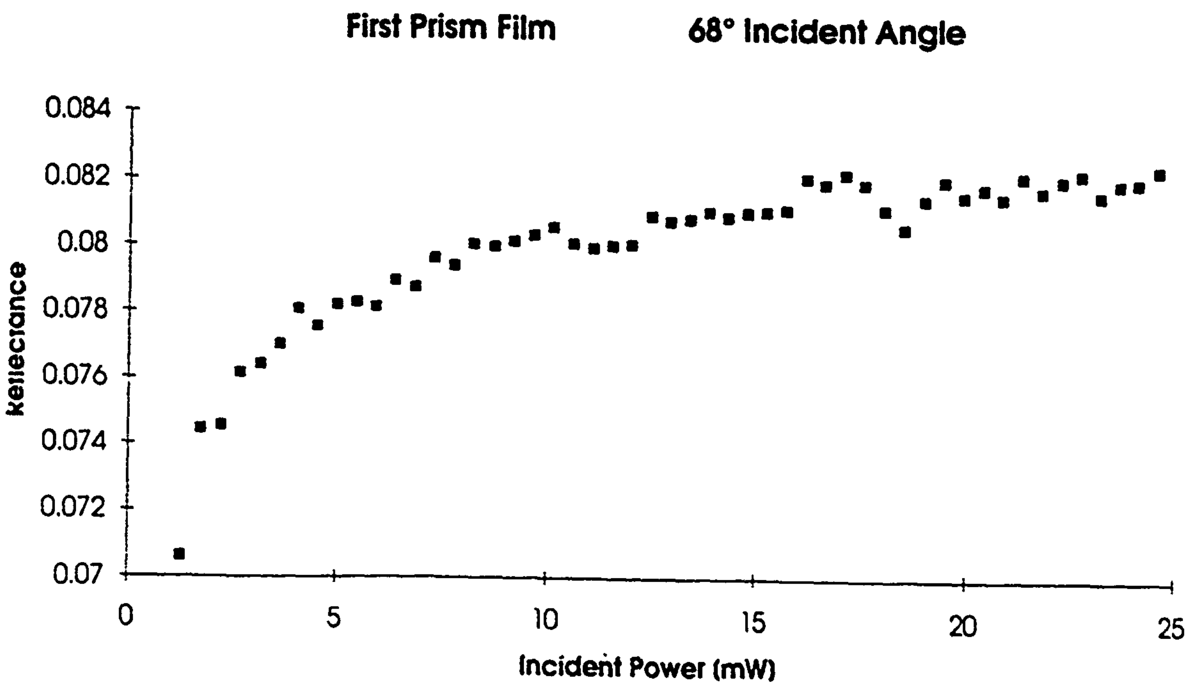


Figure 19. Power Dependence of Reflectivity/Prism Substrate

index of refraction. Our first approach involved use of the crossing angle ,ϑ_1, between reflectance vs angle curves for the blank substrate and the film-substrate system. Figure 14 shows such a set of curves. The index of refraction of the film can be shown to a function of the crossing angle, i.e. ≈60°C for the data shown. The fact that the reflectance curves for the film system are apparently not identical at two different laser powers strongly suggests that the films are photorefractive. The fact that the reflectivity curves of the same blank substrate are indistinguishable at the two different laser powers shows both the reproducibility of the measurements and the poor photorefractivity of commercial quartz.

Since we require the index of refraction of the films as a function of laser power, and there are geometric ambiguities concerning interpreting the interaction as a function of angle, we instead devised a method to determine the index of refraction of the films for a given angle. This method is described using Figure 15 and is a direct application of the Fresnel equations(see Figure 13). The index of refraction of the films effectively determines the angle of incidence of the light with respect to the film substrate interface so the equations are solved repetitively for a range of values of the film index n_2. Useful tables and graphs such as are shown in Figures 16 and 17 can be constructed using these equations which relate measured reflectivities to values of the film index of refraction. Given the known values for the index of refraction of the substrate, the film thickness measured using profilimetry, the wavelength of the light and the other nonadjustable parameters given in Figure 15, Figures 16 and 17 give the index of refraction of the film at either 488 nm or 514 nm based on the measurement of the net reflectivity *without any adjustable parameters*. Also shown is representative data obtained from the switches. Figure 18 shows data relating the measured index of refraction of a switch as a function of incident power. Considering the reproducibility of our reflectance measurements, each of the data points in Figure 18 could have vertical error bars on the order of 0.005. The totality of our results suggest that index changes on the order of 10^{-2} for application of 1-10^2 mW onto spot sizes having 10^1-10^2 diameters are probable.

The other type of procedure involved putting the film on the hypotenuse of a right triangle prism. This allowed use of angles very close to that required for total internal reflection within the film volume. Such an arrangement was first employed by Tomlinson et al in their proof of principle research. Figure 19 shows two such graphs in which the net reflectivity is plotted as a function of the laser power for a fixed angle of incidence. The curves are clearly nonlinear in a way which is different from a blank substrate.We have not yet converted these reflectance measurements into index of refraction measurements but it is clear that a Fresnel equation approach along the lines described above would be applicable.

Results

To motivate a discussion of our results on the testing of nonlinear interface optical switches, it is necessary to present some background on materials and device fabrication.

Materials and Device Fabrication

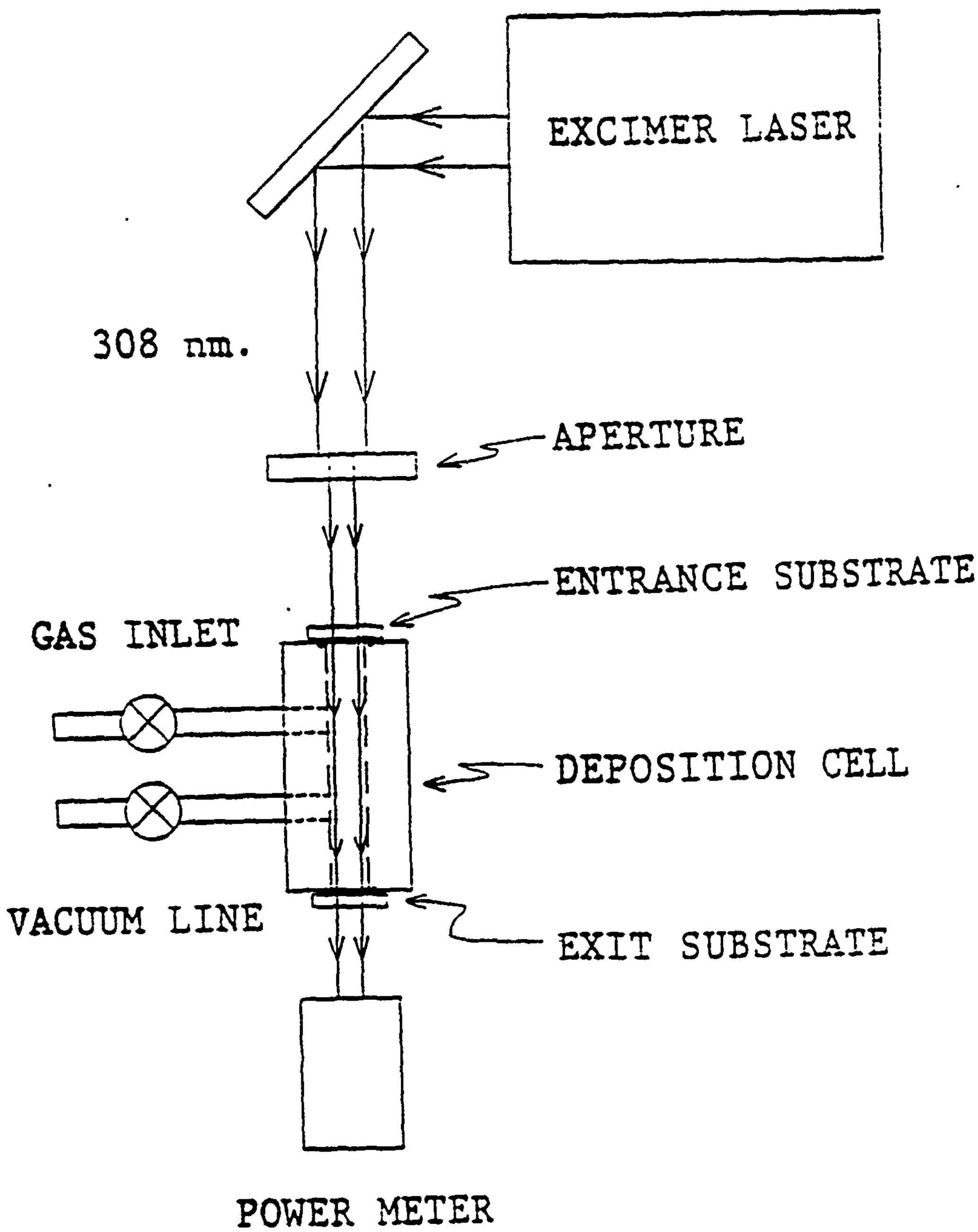
A variety of theoretical studies support the expectation that metal clusters[4], metal oxide clusters[5], dielectric coated metal clusters[6], and even dielectric coated voids[7] in thin metal films will have an enhanced electrical polarizability compared to materials with the same chemical composition but without the the submicroscopic physical features. Thin films of such materials should have enhanced photorefractive properties leading to applications[8] in nonlinear optics, optical computing and related technologies. We have recently shown[9,10,11] how to deposit thin films composed of platinum clusters using laser chemical vapor deposition(LCVD). Such films have the unusual optical/electrical property of being "transparent metal" electrodes suggesting various applications. LCVD cluster synthesis utilizing non-noble metals is fundamentally different from that of other metals so we now present recent results demonstrating the synthesis of non-noble metal and metal oxide clusters and thin films composed of such clusters. In the particular case we describe below, we use gas phase metal carbonyl precursors. As it turns out, we also demonstrate the unanticipated result that carbonyl impurities are localized on the surfaces, regardless of whether metal or metal oxide clusters are synthesized.

Although the present results relate to tungsten and tungsten oxide cluster films, the chemistry is directly applicable to other oxidizable metals. Puretsky and Demyanenko[12] report that gas phase clusters and ultrafine particles can be synthesized using excimer laser dissociation of all group six metal hexacarbonyls. Our earlier work on platinum clusters and our current results on other metals both suggest that the clusters which are present in our films are formed by gas phase processes. In fact, many[13,14,15] have studied UV dissociation, in both single and multiphoton limits, of metal hexacarbonyls in the context of depositing thin films for microelectronic device fabrication. Incorporation of partially decarbonylated species and reaction products derived from these species are a disadvantage of LCVD of metallization patterns for microelectronic applications. We have recently shown that use of noncarbonylated precursors in laser chemical organometallic synthesis of platinum clusters also results in incorporation of organic impurities but that they can be removed and potentially utilized via post-deposition chemistry. Gas phase and post-deposition chemistry is limited by the tendency of the metal to oxidize which makes the results we now present quite distinct from our earlier LCVD platinum results.

A diagram of the apparatus used to perform LCVD of free standing tungsten and tungsten oxide cluster films on transmission electron microscopy(TEM) grids and on GaAs and Ge substrates is shown in Figure 20[6]. The tungsten hexacarbonyl($W(CO)_6$) was purified by sublimation before being loaded into a specially designed all stainless steel gas/reactant delivery system. This system utilizes a molecular sieve drying tube to remove water from argon carrier gas which was used to entrain the tungsten hexacarbonyl. A set of MKS capacitance manometers and isolable chambers of known volume to measure partial and total pressures and flow rates in the delivery system and in the deposition cell. Although this apparatus will be described in greater detail later[16], it suffices to point out that utilizing a series of micrometer valves, and lengths of tubing with various internal diameters, the total pressure, flow rate, gas stream composition and temperature could each be independently adjusted.

Figure 21 shows a TEM of a free standing tungsten film deposited by LCVD directly onto a TEM grid at x2500 magnification. At much higher magnification, x150,000, globular clusters are clearly visible. Electron diffraction of one of these nodules indicated by an arrow was performed and only interplanar spacings of tungsten are evident[17]. The tungsten clusters are produced using 20 millitorr of tungsten hexacarbonyl at 62°C with argon added to produce a total pressure of 70 mtorr in the deposition cell. This pressure is lower than the vapor pressure of bulk tungsten hexacarbonyl at the same temperature because we are working in a flowing cell. Figures 21a, b and c show essentially the same data obtained for tungsten oxide clusters. These clusters were deposited using the same partial pressure of tungsten hexacarbonyl but with the rest of the total pressure being composed using O_2. The near coalescence of the diffraction rings into spots presents an interesting comparison with the results of Mader[18] and Aspnes[19] consistent with the idea that our films are composed by condensation of clusters of varying sizes.

Figure 20. Laser Chemical Vapor Deposition Apparatus



Laser Chemical Vapor Deposition Apparatus particular overlay. Editor overlay is a simple ASCII text editor for altering user defined ASYST text programs. Although it is not needed, it is more convenient than leaving ASYST, loading another ASCII editor or word processor, and then returning to ASYST. If you plan on using the menu command words for driving your programs than you should load the overlay ***Menu Tools***. Other suggested overlays to load are ***Data Files***, and the ***Lotus 1-2-3 File Interface*** found in File Overlays. This section is also important in minimizing the memory that these overlays use. After selecting the overlays you desire and press Escape, the program will ask if you want to permanently store them. Answer yes, otherwise the overlays you selected will not be loaded. Be sure of your choices or you may have to start all over.

Available Overlays	Selected Overlays
Editor	Editor
Help System	Data files
Array Editor	Lotus 123 File Interface
RS-232	GPIB Master
Algebraic Parser	Type 2 NEC GPIB driver
Menu Tools	Menu Tools
File Overlays	PCX File Support
Graphics Overlays	Pixel
Analysis Overlays	
Data Acquisition	
GPIB	
External Interfaces	

Available Memory	
Base Dictionary:	5816
Symbol Table:	4101
Overlay Memory:	5615
String Segment:	6074
Array Memory:	48548

Type: O - for overlay description
W - to find a desired word
<esc> - exit menu

Figure 6. ASYST Overlay Selection Menu

GPIB Board Configuration:

After entering the board's bus number, which is usually zero, you can select which GPIB board your PC has from the highlighted list of choices. If your GPIB board is listed but not highlighted you must return to the Overlay Configuration and choose the correct driver overlay. Refer to ASYST Module 4 GPIB/IEEE-488 Appendix D for a list of supported boards and their driver overlays. The program will then ask several questions for configuration depending on which type of GPIB board your computer uses. You will want to have ready the base address, interrupts, and controller address.

Memory Configuration:

This configuration menu is very important (Figure 7). ASYST uses only conventional memory (except for tokens) which can fill up quickly

Minimize System

After a final system has been constructed by loading in all needed overlays in the Overlay Configuration menu, the size of the system may be minimized. This will free up some space in the system for other areas of memory (those in the next menu). Note that once this is done to a system, no more overlays may be added using the Overlay Configuration menu. (therefore, be careful not to minimize the original copy of ASYST.) Also note that this minimization will not be available unless a Save is made when leaving the main config menu.

Minimize System (Y/N): <Y>

Leave room to load system transient overlays (Y/N): <Y>

Press 'Y' or 'N' and then press Esc to continue.

Figure 7. ASYST Memory Configuration

with large programs and/or many overlays *[I:11-24]*. To get the most out of the ASYST memory configuration ensure that you have permanently loaded into memory only the overlays that you need from the Overlay Menu. Then select 'yes' for ASYST to automatically minimize your system memory form the memory configuration menu. If you are sure you will not be needing any more overlays, do not allow room for loading transient overlays. Allowing room for one transient overlay takes up 36K of conventional memory space. Depending on your intended use the target memory can be changed to suit your needs. As you program in ASYST you can check your memory usage at the OK prompt with ***?memory***. If you find you're running out of room for one particular target memory, go back to the memory configuration menu to make changes in memory. Reassign memory according to your needs. You may want to delete all of your defined words before changing your memory, otherwise the memory configuration will be permanently saved with your currently defined word definitions. You may need to increase your conventional memory from DOS. This can be done by not installing devices such as *fastopen*, *setver*, and *mouse.com* in your *Config.sys* and *Autoexec.bat* files into memory. If you have a 386 you can use the DOS expanded memory manager, or a similar manager such as the *Quarterdeck QEMM-386*, to load these and other devices into high memory.

Saving ASYST Configurations

You can save your configurations when you try to exit the configuration menu or type save ***filename.ext*** at the OK prompt. Both procedures create a .ovl and a .com file to execute from the DOS prompt. You can save your configurations with your defined words or text programs loaded into memory. This saves time in loading them every time you enter ASYST from the DOS prompt. GPIB users keep in mind that if you were already initialized and "talking" to GPIB devices when you made the save, you still must re-initialize the GPIB bus when you run your saved program. A special note, all arrays and tokens are emptied during this save. Arrays keep their size, but not their data. Tokens lose size, data and place in memory if you had them put into expanded memory.

Figure 21. (a) TEM photo of high pressure tungsten film and (b) corresponding electron diffraction pattern. (c) TEM photo of high oxygen pressure film and (d) corresponding electron diffraction pattern.

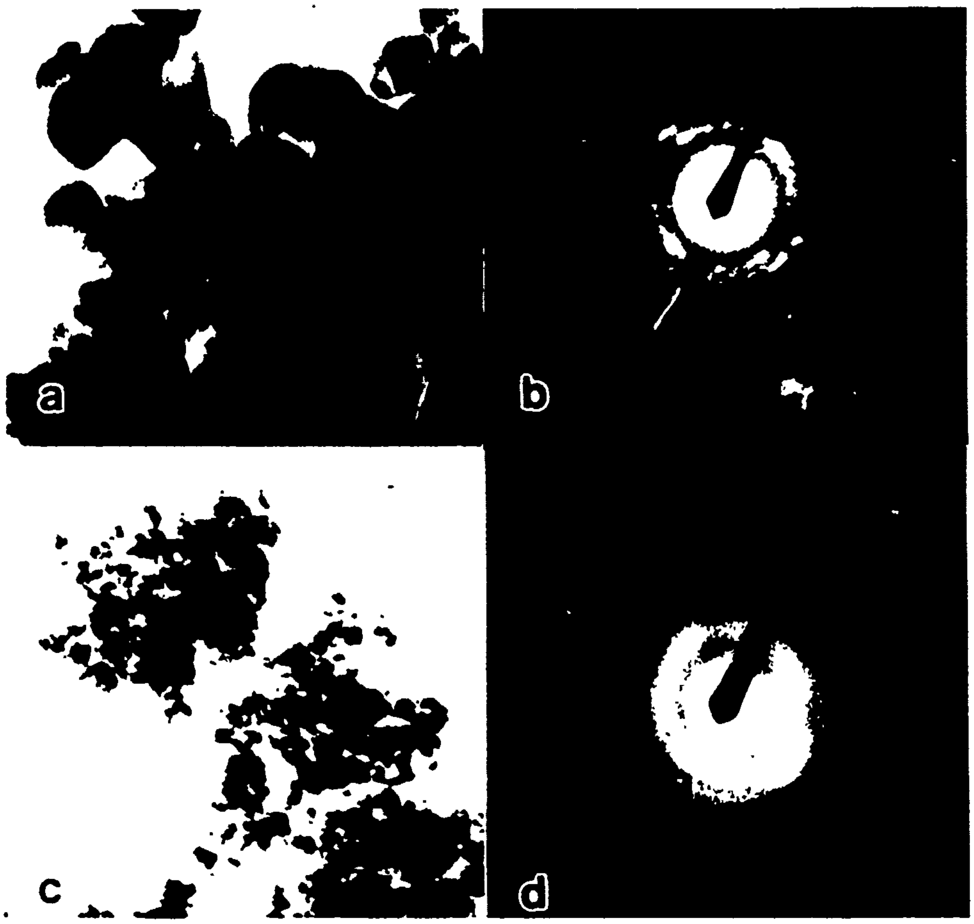


Figure 22. Cluster Film Formation Process

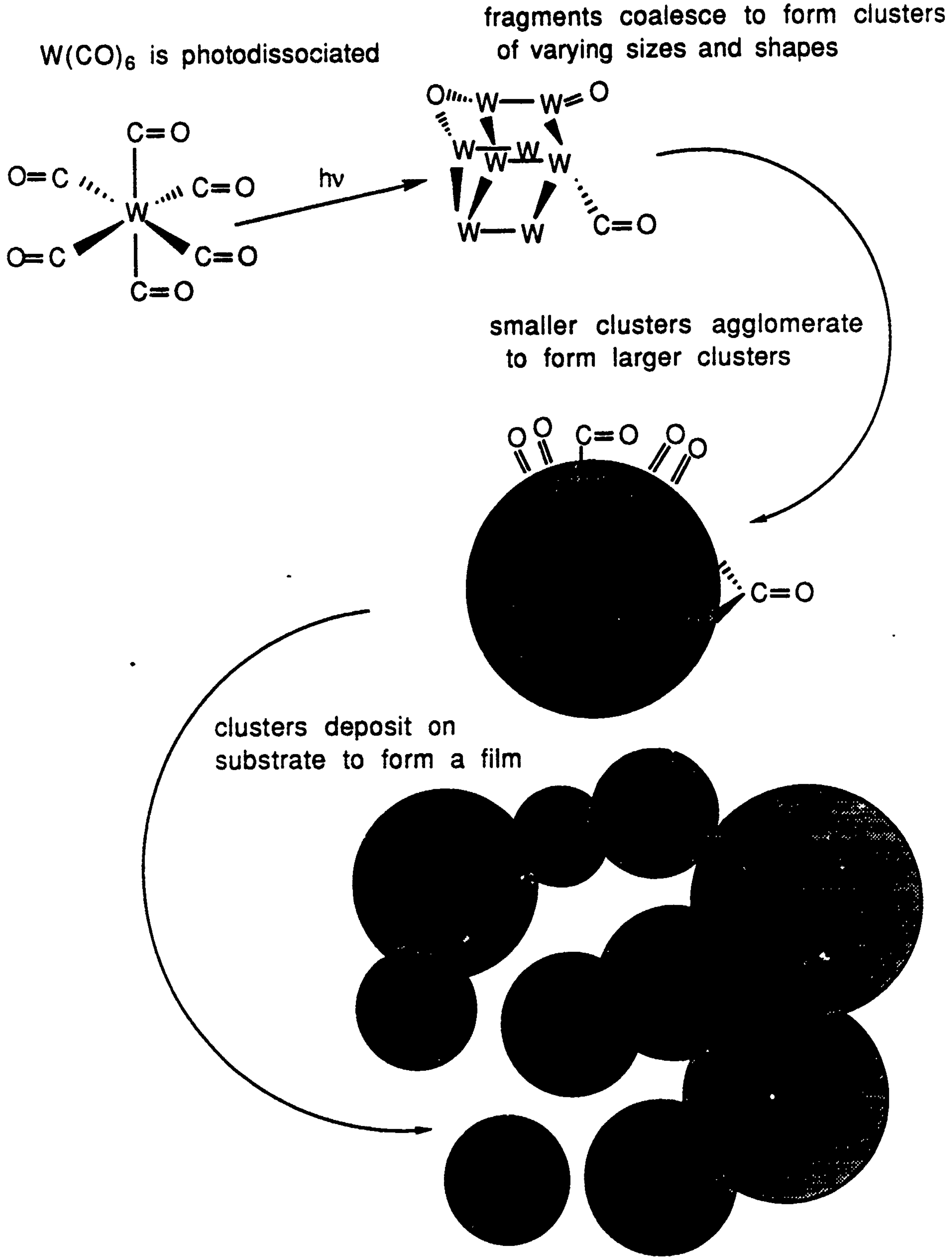


Figure 23. FT-IR Spectra of Aged and Nascent Film

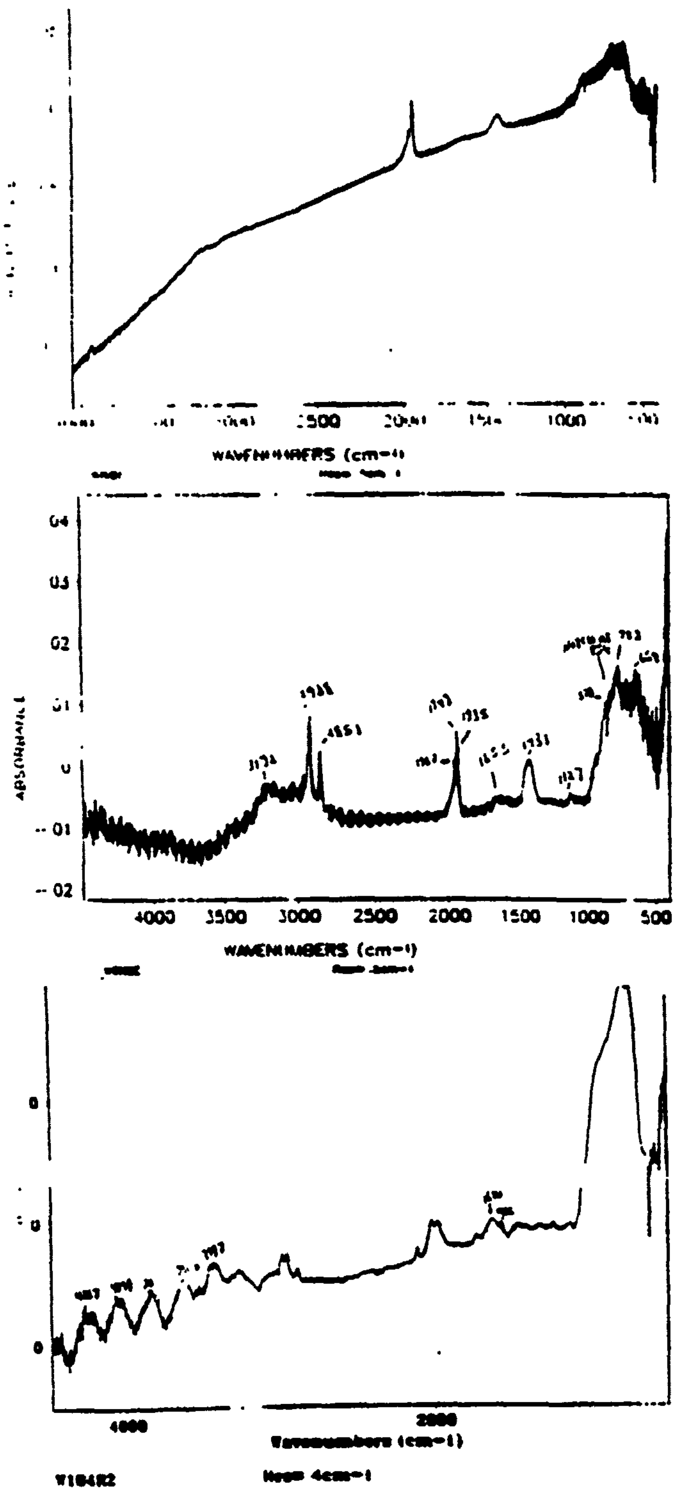


Figure 22a shows an Fourier Transform Infrared Absorption Spectrum(FT-IR spectrum) of a nascent tungsten film deposited as described above onto a Ge substrate. There is evidence of a surface oxide[20] which probably forms immediately upon exposure of the film to the atmosphere. The carbonyl stretches are clearly visible and occur at 1935, 1942, and 1962 cm^{-1}. All of these frequencies are too high to be characteristic of bridging carbonyls suggesting that the carbonyl does not exist in an environment conducive to bridging between metal atoms. This almost rules out an environment internal to the clusters. An FT-IR of the same film aged in air for nearly a year clearly which can be seen in Figure 22b shows that the carbonyls have reacted with airborne oxygen further suggesting that they could not have been buried deep in the cluster. The carbonyl stretching fundamentals are still clearly visible and are not characteristic of bridging interactions[21]. Figure22c shows a nascent film which was deposited under identical conditions for LCVD production of the metal oxide clusters. The carbonyl stretches(1969, 2008, 2106 cm^{-1}) are again clearly visible and not characteristic of bridging. In both Figure 22b and 22c, the sharp FT-IR features just below 3000 cm-1 are as yet not unambiguously assignable. We currently believe they can be identified with formate formed by the catalytic coupling of water and CO which we believe could occur on the cluster surfaces. Although we are currently performing a variety of experiments to support this assertion, if our surmisal is correct, the water could be supplied from the substrate or the atmosphere.

The TEM results demonstrate the existence of clusters. The FT-IR results show that bridging carbonyls are never present in either nascent or films extensively aged in air. Reactions of the carbonyls associated with the films are indicative of surface bound carbonyl. We are currently pursuing other chemical means of utilizing the carbonyl impurities as reactant for producing composite films from the nascent LCVD films we have shown here.

Heating the tungsten oxide films in vacuum and in an oxygen environment has potentially useful consequences. Raman spectroscopy shows that such films heated in oxygen begin to show features at $\approx 800cm^{-1}$ indicative that the tungsten-oxygen begin to organize themselves into octahedra. This is significant because such octahedra are thought to be necessary for the photorefractive effects observed in titanates and niobates. Heating the films in vacuum produces peculiar blue films which ESCA shows contain tungsten in the +4 oxidation state. This is significant because such electron rich species might be able to provide highly polarizable charge carriers. These charge carriers would enhance the photorefractive properties of the films. ESCA of nascent laser deposited tungsten oxide films clearly show the presence of small amounts of tungsten +5 which is necessary to produce tungsten bronzes. Other metal ions, involving e.g. Ti^{+2}

and Nb^{+2}, analogous to these unusual W species, are required to achieve the photorefractive properties of the well known titanate and niobate photorefractive materials.

Correlation of film composition with static and dynamic index of refraction measurements is best accomplished using ESCA, UV-visible and infrared spectroscopic methods in both absorption and reflection. Current plans involve use of Kramers-Kronig relations to obtain complete index measurements across the entire IR-UV spectrum. Film composition is not well determined by Auger spectroscopy because of electron beam induced changes in the film and because of the small spot size in which measurements are made. Using Auger, the spot size is commensurate with the size of the clusters and so many measurements must be made to obtain accurate average values for the film metal-oxygen stoichiometry.

Discussion

We have demonstrated that we have provided films composed of metal oxide clusters. We have measured two types of optical data both of which suggest the films have measurable nonlinear susceptibilities. Attempts to quantitate the amount of refractive index change are imprecise but, for films ≈200Å thick, could be as high as 10^{-1} $Watt^{-1}$ at 514 nm. Obtaining precise estimates is possible but reproducibility makes it a challenge. Use of a prism hypotenuse as a switch substrate seems to give an output which is much more sensitive to the film's photorefractive response. These results will be discussed in the context of the switch evaluation and the design criteria and properties of the nonlinear interface approach to switches in general.

Given the multitude of predictions which have been made considering the optical and electrical properties of clusters, we felt it important to definitively establish their presence in the switches we were able to fabricate. We varied fabrication conditions such that the cluster size distribution varied from an average of about a few 10^1Å in diameter to multi-10^2Å diameters.Based on existing calculations, clusters in the size range $\lambda/10$ to 1.5λ should possess enhanced nonlinear optical properties. The data suggests: 1) we have developed the capability to observe photorefractive effects with great sensitivity, and 2) it may well be true that we have already observed some very large effects. We are cautiously encouraged by these results but we know that more work is required to make unequivocal statements.

One problem is the difficulty in establishing the reproducibility of the results. Further, the results we currently have are not yet good enough to suggest a physical mechanism underlying the photorefractive properties, i.e. a χ^3 or χ^2 effect. Since we have established that the quartz substrates have extremely small nonlinear optical coefficients, any change in the reflectivity can be taken to be mostly caused by the film's properties. Since the refractive index can be readily related to the induced polarization, which in turn can be related to the applied optical intensity via the usual expansion in the nonlinear susceptibility, given better data we know we will be able to determine the type of interaction leading to the photorefractive effects.The data in the figure is typical of what we have obtained repeatedly. Recall that we showed in Figure 17 that we can collect extremely reproducible data. This has led us to suggest that the films are somehow being irreversibly changed by the evaluation process. The chemistry we have observed using FT-IR clearly shows that there is some irreversible chemistry which occurs over very long periods of time. Perhaps the testing regimen accelerates this process. We employed the analytical methods mentioned in the Results section to discover the possible modifications which could be taking place.

However, so far all methods we used to analyze the films were static methods. It is quite possible that the photorefractive effects we are observing occur on the timescale of the laser pulses, i.e. 100 psec. Such effects would not be unambiguously observable using the static methods so far employed. Note that the fastest photorefractive effects, would be based on nonresonant interactions and that these would certainly only be observable on the timescale of the laser pulses or faster. The fastest photorefractive responses are those involving the smallest amount of movement of mass. Purely electronic motions are therefore obviously the fastest. The only way to definitively explore these possibilities is to use single pulse pump-probe experiments which are planned for the near future. Based on UV-visible spectroscopy, we plan experiments at longer wavelength, 800-900nm, which should be more nearly resonant with an absorption and therefore even more strongly photorefractive. What we lose in speed might be compensated for in the strength of the response.

Perhaps the most interesting result of this study is the sense that the nonlinear optical properties of the clusters are very impressive. Since the switches we have tested are composed of films we have shown to be nominally ≈200nm thick, and the clusters average 10^2Å in diameter, it is clear that the films are only 10-20 clusters thick. For a spot size of 50μm in diameter, a conservative estimate, only 10^4-10^5 clusters are being used to produce a single element switch. This suggests that the theoretical shot noise limit on the signal to noise ratio for a single shot test of the switch should be ≈100. Lack of uniformity of the films, in either thickness and/or composition, will only degrade this expectation. Since the spot size changes shape and size as the angle of incidence is varied, uniformity can clearly become an issue. However, for a test in which the angle of incidence in kept constant while ramping the incident power, the growth in focal volume, due to diffraction, imposes must less stringent constraints. Thus, the total internal reflection configuration, Figure 1b, should definitely be the choice for future nonlinear interface optical switch work.

Simulations strongly suggest that use of substrates like ZnS will be advantageous in all switching application because they more closely match the static index of the film(s). The effects we observe are almost certainly purely electronic in nature and involve no movement of mass whatsoever. Attempts to make cluster films which are thicker have not been successful so far. This is because we have needed to modify our deposition apparatus. Currently, as the films get thicker, they begin to undergo ablation about as much as thickening by additional deposition. This problem can be overcome by using LCVD without contacting the films. Thicker films will allow more clusters to be involved in the switching process and should therefore increase the photorefractive response.

Conclusions

The films used for implementing nonlinear interface switches may indeed display large photorefractive effects. The evaluation of such switches must be carried out using single pulse, pump-probe methods to eliminate the possibility of artifacts. A total internal reflection configuration is strongly indicated for implementing switch devices in future effort. It is clear the best embodiment of a nonlinear interface switch is with a prism as a substrate. Use of planar substrates has allowed definite determination of the static index of refraction of the films. Use of prism substrates allows use of an angle of incidence which is so close to the critical angle for total internal reflection at the film-air interface that the only leakage through the film is due to the angular divergence of the laser beam.

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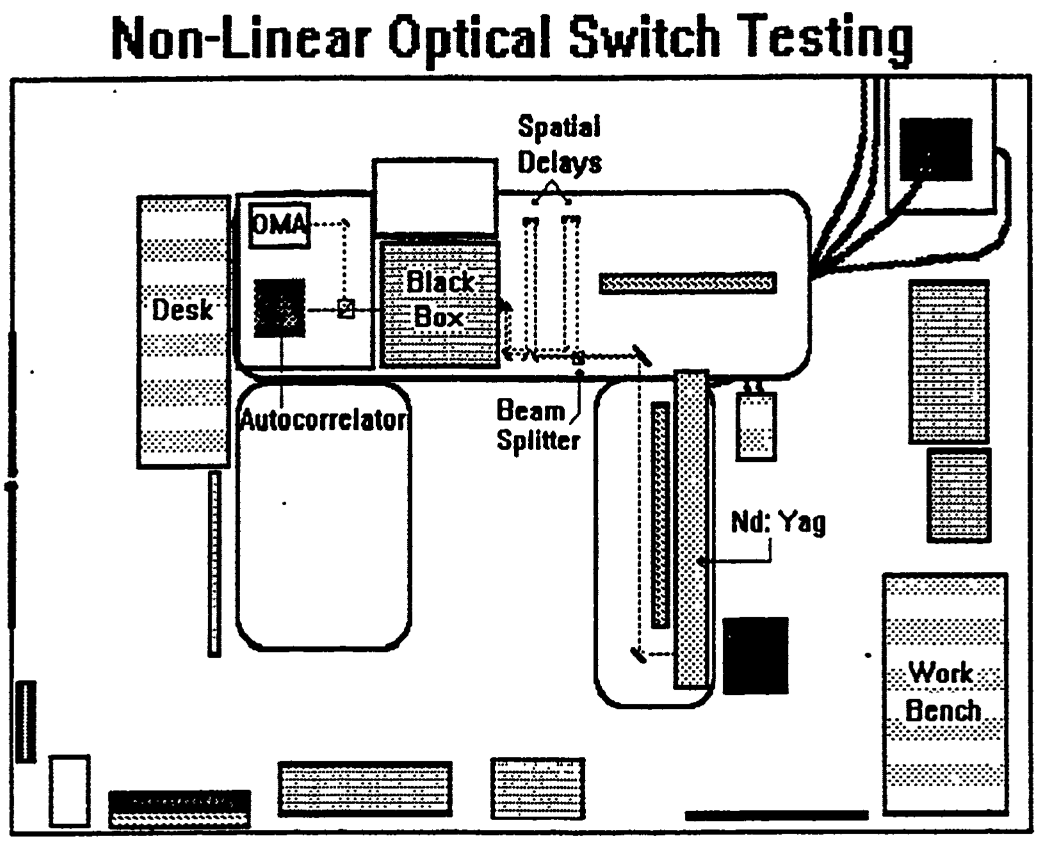
Appendix A - Diagram of Laboratory



Appendix B - Program: GPIB.XXX (Main Menu)

```
GRAPHICS.DISPLAY VUPORT.CLEAR       \  CLEAR ALL ASYST STACKS
NORMAL.DISPLAY FORGET.ALL           \
SS.CLEAR STACK.CLEAR                \
ECHO.OFF                            \
\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
\                                                                         \
\                      MENU FOR GPIB OPERATING DEVICES                    \
\                                                                         \
\                           by Brian K. DeVaul                            \
\                                                                         \
\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
\                                                                         \
\   Some commonly used commands have been shorten to save typing          \
\    speed. There is a list of the newly defined words in the file        \
\   called GPIB2.XXX.                                                     \
\                                                                         \
\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\

\ ************** LOAD OPERATING SUBFILES FOR GPIB PROGRAM *************** /

LOAD GPIB2.XXX                       \   SHORT COMMANDS FILE
LOAD GPIB3.XXX                       \   GPIB CONFIGURATIONS
LOAD GPIB4.XXX                       \   COMMON VARIABLES

\ ************** DEFINE GPIB MAIN MENU SPECIFIC VARIABLES **************** /

 INTEGER SCALAR NUMBER.OF.MODULES
 INTEGER SCALAR FIRST.LOAD
 INTEGER DIM[ 50 ] ARRAY CMDAT
 36 STRING MODULE.MENU
 DIM[ 21 , 36 ] STRING.ARRAY MODULES
 DIM[ 21 , 36 ] STRING.ARRAY MODULES.DESC
 0 FIRST.LOAD :=
 0 NUMBER.OF.MODULES :=
```

```
\ **************** DEFINE OPERATING COLON DEFINITIONS ******************** /

: MOUSE
       0 0 0 0 CALL.MOUSE 4 *DROP
       65535, SET.MOUSE.INT
       13 27 SET.MOUSE.BUTTONS
       3 0 0 0 CALL.MOUSE 4 ROLL DROP ;

: LOAD.GPIB.MODULES

     FILE.OPEN DATAFILE.XXX
         20 1 DO I      COMMENT> MODULES      "[ I ] ":= LOOP
         20 1 DO I 20 + COMMENT> MODULES.DESC "[ I ] ":= LOOP
         1 SUBFILE CMDAT FILE>ARRAY
     FILE.CLOSE

     21 1 DO              \ COUNT THE NUMBER OF MODULES BEING LOADED
        CMDAT [ I ] 1 = IF   Z 1 + Z :=   THEN
     LOOP   Z NUMBER.OF.MODULES :=

     1 CMDAT [ 22 ] = IF 1 FIRST.LOAD := 0 CMDAT [ 22 ] := THEN
                          \ DETERMINES IF THE MENU CONFIGURATION WAS USED

     11 1 DO      CMDAT [ I ] 1 =  \ LOAD MODULES DESIGNATED IN CMDAT
        IF  " LOAD " MODULES "[ I ] -TRAILING "CAT  \ LOAD  name.XXX
            " .XXX" "CAT "EXEC SS.CLEAR             \
        THEN                                        \
     LOOP                                           \
     1 CMDAT [ 11 ] = IF MOUSE THEN ;               \ IF DESIGNATED, LOAD
                                                    \ MOUSE SUPPORT

\ ******************** LOAD DEVICE SPECIFIC SUBFILES ******************** /

LOAD.GPIB.MODULES     \ USE COLON DEFINITION FOR LOADING
LOAD GPIB5.XXX        \ LOAD MENU CONFIGURATION MENU
```

```
\ ************************   Designing the MAIN menu   ****************** \

: PROMPT     MENU.ESCAPE ;

: LOAD.MENU.ITEMS                          \ SETUP MENU OPTIONS FOR THE LOADED
     3 X :=  NUMBER.OF.MODULES Z :=        \  MENU PROGRAMS
    20 1 DO         CMDAT [ I ] 0 =        \
       IF                                  \
       ELSE  Z 7 <                         \
             IF X 2 + X := ELSE X 1 + X := THEN
          "  MENU.ITEM( " MODULES "[ I ] "CAT " .MENU " "CAT " )" "CAT
          MODULE.MENU ":=
          X 5 MODULES.DESC "[ I ] MODULE.MENU "EXEC
       THEN
    LOOP
     5 Z :=               \ OFFER MENU CONFIGURATIONS IF THERE
     0 FIRST.LOAD =       \   WASN'T A PREVIOUS SAVE
     IF 5 45 " MENU CONFIGURATIONS"  "  MENU.ITEM( CONFIG.MENU )" "EXEC
     ELSE  THEN ;

:  MAIN.STAT              \ ITEMS TO BE DISPLAYED WITH MAIN MENU
    4 FIRST.LOAD = IF 2 FIRST.LOAD := CONSOLE MENU.ESCAPE THEN
    12 FOREGROUND
    60 1 GOTO.XY ." DATE: " "DATE "TYPE      \ DISPLAY CURRENT DATE
    9 FOREGROUND
    40 16 GOTO.XY ."  USAF PHOTONICS CENTER"
    40 17 GOTO.XY ."  GRIFFIS AIR FORCE BASE"
    40 18 GOTO.XY ."      ROME, NEW YORK"
    10 FOREGROUND
    60 21 GOTO.XY ." by Brian DeVaul"
    11 FOREGROUND ;

MAIN.MENU                                  \ DEFINED MENU NAME ( GPIB4.XXX )
   " GPIB DEVICE MAIN MENU" MENU.TITLE     \
   MENU.STATUS MAIN.STAT                   \ DISPLAY COLON DEFINITION
   MENU.BLOW.UP                            \
   1 1 24 78 MENU.SHAPE                    \ SIZE OF THE MENU
   0 11 MENU.COLOR                         \ FOREGROUND AND BACKGROUND COLORS
   15 MENU.PROMPT.COLOR                    \ HIGHLIGHT COLOR
   LOAD.MENU.ITEMS                         \ LOAD MENU OPTIONS
   7 45 " EXIT TO THE  'OK'  PROMPT" MENU.ITEM( PROMPT )
   9 45 " EXIT TO DOS" MENU.ITEM( BYE )
MENU.END
```

```
\ \\\\ START MENU PROGRAM

: START
  11 1 DO  CMDAT [ I ] 1 =     \ RELOAD TOKENS AND ARRAYS THAT ERASED DURING
     IF " RELOAD." MODULES "[ I ] "CAT "EXEC THEN  \   SAVE.
  LOOP
  SCREEN.CLEAR
  INIT                         \ INITIALIZE GPIB
  MAIN.MENU MENU.EXECUTE ;     \ BEGIN MENU PROGRAM

: GO      START ;

: CONFIG.RESTART               \ SAVE NEWLY CONFIGURED PROGRAM AFTER RELOADING
  1 FIRST.LOAD =               \
      IF FILE.OPEN DATAFILE.XXX    41 COMMENT> FILE.NAME ":=
         2 FIRST.LOAD := 1 SUBFILE CMDAT ARRAY>FILE  FILE.CLOSE
         " SAVE " FILE.NAME "CAT "EXEC
        INIT                         \ INITIALIZE GPIB
      ELSE
     THEN ;
CONFIG.RESTART                 \ IF THIS FIRST TIME LOADED, FIRST.LOAD = 0
```

Appendix C - Program: GPIB2.XXX (Shortened Commands)

```
\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
\                                                                       \
\                       SHORT COMMANDS FOR ASYST                        \
\                                                                       \
\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
\                                                                       \
\   Some commonly used commands have been shorten to increase typing    \
\    speed. Here is a list of the newly defined words.                  \
\                                                                       \
\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
                                    \
 : GD GPIB.DISPLAY  ;               \    GD = GPIB.DISPLAY
 : ND NORMAL.DISPLAY ;              \    ND = MORMAL.DISPLAY
 : SD STACK.DISPL Y   ;             \    SD = STACK.DISPLAY
 : SC STACK.CLEAR      ;            \    SC = STACK.CLEAR
 : ?GDS ?GPIB.DEVICES    ;          \  ?GDS = ?GPIB.DEVICES
 : ?GD ?GPIB.DEVIC  ;               \   ?GD = ?GPIB.DEVICE
 : GPD GPIB.DEVICE  ;               \   GPD = GPIB.DEVICE
 : GW GPIB.WRITE  ;                 \    GW = GPIB.WRITE
 : GR GPIB.READ  ;                  \    GR = GPIB.READ
 : ?SRQD ?SERVICE.REQUEST DROP ;    \ ?SRQD = ?SERVICE.REQUEST DROP
 : SPD SERIAL.POLL DROP ;           \   SPD = SERIAL.POLL DROP
 : []GB []GPIB.BUFFER ;             \  []GB = []GPIB.BUFFER
 : BL BUFFER.LISTEN ;               \    BL = BUFFER.LISTEN
                                    \
 : T TALK ;                         \     T = TALK
 : LI LISTEN ;                      \    LI = LISTEN
                                    \
 : INIT                             \ INITIATE GPIB DEVICE CONTACT
     BUS.INIT                       \  1)  INITIATE BUS
     SEND.INTERFACE.CLEAR           \  2)  CLEAR INTERFACE
     REMOTE.ENABLE.ON  ;            \  3)  TURN ON REMOTE
                                    \
 : F FORGET.ALL       ;             \ CLEAR TEMPORARY DEFINITIONS

 : FA  GRAPHICS.DISPLAY  VUPORT.CLEAR NORMAL.DISPLAY F ;
                                    \ CLEAR DEFINITIONS TO INCLUDE GRAPHICS
 : CFK CLEAR.FUNCTION.KEYS  ;       \ CLEAR FUNCTION KEYS
 : FKD FUNCTION.KEY.DOES    ;       \ CHANGE FUNCTION KEY OPERATION

 : DG                               \ DELETE DEFINITIONS, GRAPHICS
     GRAPHICS.DISPLAY               \  AND RETURN TO ASCII TEXT EDITOR
     VUPORT.CLEAR ND F              \
     EDIT                           \
 ;
```

Appendix D - Program: GPIB3.XXX (GPIB Device Configurations)

```
\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\ \
\                                                                              \
\                         GPIB CONFIGURATION FILE                              \
\                                                                              \
\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\ \
\    INSTRUCTIONS:                                                             \
\                                                                              \
\          1) PgDn to Device to be Changed.                                    \
\                                                                              \
\          2) Edit the Parameters of the Device.                               \
\              a)  The name of the device follows the command                  \
\                      GPIB.DEVICE as follows ;                                \
\                    ex.  1 GPIB.DEVICE Device.Name                            \
\                  where 1 is the Primary Address for the Device.              \
\             b) The End Of String (EOS) character is configured in            \
\                  ASCII code.                                                 \
\                    ex.    10 EOS.CHARACTER                                   \
\                  where 10 is ASCII for Line Feed. Consult an ASCII table     \
\                  for correct codes.                                          \
\                                                                              \
\          3) When you are finished editing,                                   \
\                  a) Press F9 to save the new configuration.                  \
\                  b) Then Press F10 to exit the Editor.                       \
\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\ \

    1 GPIB.DEVICE DEV1            10 EOS.CHARACTER        EOS.ON
    2 GPIB.DEVICE DEV2            10 EOS.CHARACTER        EOS.ON
    3 GPIB.DEVICE DEV3            10 EOS.CHARACTER        EOS.ON
    4 GPIB.DEVICE NWPM835         10 EOS.CHARACTER        EOS.ON
    5 GPIB.DEVICE DEV5            10 EOS.CHARACTER        EOS.ON
    6 GPIB.DEVICE DEV6            10 EOS.CHARACTER        EOS.ON
    7 GPIB.DEVICE DEV7            10 EOS.CHARACTER        EOS.ON
    8 GPIB.DEVICE LPC             10 EOS.CHARACTER        EOS.ON
    9 GPIB.DEVICE DEV9            10 EOS.CHARACTER        EOS.ON
    10 GPIB.DEVICE DEV10          10 EOS.CHARACTER        EOS.ON
    11 GPIB.DEVICE DEV11          10 EOS.CHARACTER        EOS.ON
    12 GPIB.DEVICE MC4A           10 EOS.CHARACTER        EOS.ON
    13 GPIB.DEVICE MC4B           10 EOS.CHARACTER        EOS.ON
    14 GPIB.DEVICE LBA_100        10 EOS.CHARACTER        EOS.ON
    15 GPIB.DEVICE ITH385         10 EOS.CHARACTER        EOS.ON
    16 GPIB.DEVICE GEN            13 EOS.CHARACTER        EOS.ON

INIT  \ Re-Initialize after Loading
```

Appendix E - Program: GPIB4.XXX (Common Variables & Commands)

```
\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
\                                                                                    \
\                              COMMON VARIABLES                                      \
\                                                                                    \
\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\

   15 STRING COM                  \ COMmand string to talk
   3 STRING UNITS                 \ Change Units
   5 STRING COM.DATA              \ Change Parameter Data
   36 STRING CLRSCR               \ CLEAR CHANGE PARAMETER SCREEN
   "                                     " CLRSCR ":=
      INTEGER SCALAR X.C          \ X COORDINATE
      INTEGER SCALAR Y.C          \ Y COORDINATE
      INTEGER SCALAR COLUMN       \ SCREEN COLUMN
      INTEGER SCALAR YC           \ Y COORDINATE
      INTEGER SCALAR AOD          \ AMOUNT OF DATA
      INTEGER SCALAR P            \ PARAMETER NUMBER
      INTEGER SCALAR DATA.L       \ LENGTH OF DATA
      INTEGER SCALAR D            \ DATA FORMAT

               2 STRING NTS       \ NUMBER OF TESTS
              10 STRING DF        \ DATA FORMAT

    DIM[ 28 , 21 ] STRING.ARRAY DATA.TEXT.385
    DIM[ 6 , 10 ]  STRING.ARRAY DATA.FORMAT
    DIM[ 32 , 36 ] STRING.ARRAY UNITS.DISPLAY.385
    DIM[ 88 , 36 ] STRING.ARRAY UNITS.DISPLAY.SG
    DIM[ 57 , 8 ]  STRING.ARRAY DATA.TEXT.SG

   35 STRING FILE.NAME
   INTEGER SCALAR CUT     0 CUT := \ BYPASS FOR READING SAVED SETTINGS
   INTEGER SCALAR L                \
   INTEGER SCALAR M                \     AMBIGUOUS VARIABLES
   INTEGER SCALAR N                \
   INTEGER SCALAR X                \
   INTEGER SCALAR Y                \
   INTEGER SCALAR Z                \
   INTEGER SCALAR C5F      INTEGER SCALAR C5IF       INTEGER SCALAR CS1F
   INTEGER SCALAR C5B      INTEGER SCALAR C5IB       INTEGER SCALAR CS1B
   INTEGER SCALAR C5P      INTEGER SCALAR C5S1       INTEGER SCALAR CS1P
   INTEGER SCALAR CSF      INTEGER SCALAR C5S2
   INTEGER SCALAR CSB      INTEGER SCALAR C5S3
   INTEGER SCALAR CSP      INTEGER SCALAR C5S4       1 CSB :=   14 CSF :=

   DP.REAL SCALAR RX               \ REAL DATA X
   DP.REAL SCALAR RY               \ REAL DATA Y
```

```
10 STRING SS                    \ SHORT STRING
10 STRING ERROR.TRAP.ON         \
10 STRING ERROR.TRAP.OFF        \
20 STRING FILE.PATH             \
15 STRING NAME.FILE             \
36 STRING DEVICE.DESCRIPTION    \

\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
\                                                                            \
\                         DECLARE COMMON MENUS                               \
\                                                                            \
\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\

   MENU MAIN.MENU
   MENU COLOR.MENU
   MENU CONFIG.MENU
   MENU SAVE.RESTORE.MENU
   MENU STARTUP.MENU

\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
\
\                       COMMON COLON DEFINITIONS
\
\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\

                              \ RETURN TO O.K. PROMPT
 : OKP  MENU.ESCAPE MENU.ESCAPE MENU.ESCAPE MENU.ESCAPE ;

 : CLR.UNITS.DISPLAY          \ CLEAR UNITS DISPLAY
     40 1 GOTO.XY CLRSCR "TYPE
     40 2 GOTO.XY CLRSCR "TYPE
     40 3 GOTO.XY CLRSCR "TYPE   ;

                              \ CLEAR DATA DISPLAY
 : CLR.DATA  X.C Y.C GOTO.XY CLRSCR 1 COLUMN "SUB "TYPE ;

 : SAVE.RESTORE.STATUS
     5 5 GOTO.XY ." Press ENTER after typing"
     5 7 GOTO.XY ." Press ESCAPE when finished"  ;

 SAVE.RESTORE.MENU
     MENU.STATUS SAVE.RESTORE.STATUS
     MENU.BLOW.UP
     MENU.NO.PROTECT
     8 20 16 60 MENU.SHAPE
     CSB CSF MENU.COLOR
     1 2 " ENTER DIRECTORY PATH" MENU.ITEM( FILE.PATH )
     3 2 " ENTER FILENAME" MENU.ITEM( NAME.FILE )
 MENU.END
```

Appendix F - Program: GPIB5.XXX (Automated Menu Configuration)

```
MENU DEVICE.MENU                          \ DECLARE MENU

: MAKE.DEVICE.COLON.DEFINITIONS           \ CREATE COLON DEFINITIONS AS MENU
                                          \ OPTIONS TO CHANGE LOADING STATUS
     11 1 DO   MODULES "[ I ] "NULL "=    \ (ON=1, OFF=0). THE MENU OPTIONS
        IF                                \ ARE DEPNDENT UPON WHAT MODULES
        ELSE  " : " MODULES "[ I ] -TRAILING "CAT     \ ARE CURRNETLY
              " .ZZZ    CMDAT [ " "CAT I "." "CAT     \ AVAILABLE IN
              "  ] 1 = IF   0 CMDAT [ " "CAT I "." "CAT  \ DATAFILE.XXX
              "  ] := ELSE 1 CMDAT [ " "CAT I "." "CAT   \
              "  ] := THEN ; " "CAT
             "EXEC SS.CLEAR
        THEN
     LOOP ;

 MAKE.DEVICE.COLON.DEFINITIONS            \ CREATE THE DEFINITIONS WHEN THIS
                                          \ TEXT FILE IS LOADED.
: DEVICE.SELECTION                        \ LOAD THE MENU OPTIONS FROM
    3 X :=                                \ INSIDE THE MENU DEFINITION.
    11 1 DO    X 1 + X :=  MODULES "[ I ] "NULL "=  IF
       ELSE  " MENU.ITEM( " MODULES "[ I ] "CAT " .ZZZ " "CAT " )" "CAT
             MODULE.MENU ":=  X 5 MODULES.DESC "[ I ] MODULE.MENU "EXEC THEN
    LOOP  ;

: DEVICE.STAT                             \ MENU DISPLAY
     4 Z :=  15 3 DO 50 I GOTO.XY CLRSCR 1 28 "SUB "TYPE LOOP
     11 1 DO   CMDAT [ I ] 1 =
         IF 65 Z GOTO.XY MODULES "[ I ] "TYPE Z 1 + Z := THEN LOOP
     5 2  GOTO.XY ." AVAILABLE DEVICE DRIVERS"
    60 2  GOTO.XY ." SELECTED DRIVERS"
     5 23 GOTO.XY ." Press ENTER to Select"
    65 23 GOTO.XY ." ESC to Exit"    ;

DEVICE.MENU                               \ MENU SELECTIONS DEVICE MENU
   " PROGRAM CONFIGURATIONS" MENU.TITLE \
   MENU.STATUS DEVICE.STAT
   MENU.BLOW.UP
   1 1 24 78 MENU.SHAPE
   0 11 MENU.COLOR
   15 MENU.PROMPT.COLOR
   MENU.STORE.DISK
   DEVICE.SELECTION                       \ LOAD MENU ITEMS FROM PREVIOUS
MENU.END                                  \ COLON DEFINITION
```

```
: GPIB.D.C                                   \ EDIT GPIB DEFINITIONS
    TEXT.EDIT GPIB3.XXX   CR                 \
    LOAD GPIB3.XXX ;

: MOUSE.SUPPORT                              \ EDIT ON/OFF MOUSE SUPPORT
   1 CMDAT [ 11 ] =                          \ OPTION
       IF 0 CMDAT [ 11 ] :=                  \
       ELSE 1 CMDAT [ 11 ] :=
       THEN  ;

: SAVE.PROGRAM.CONFIG                        \ SAVE SELECTED OPTIONS
   35 20 GOTO.XY ." ENTER DOS ENTRY FILENAME "  \  ENTER NEW FILE NAME
   " C:\ASYST          " FILE.PATH ":=          \   FOR EXECUTABLE ASYST
   SAVE.RESTORE.MENU MENU.EXECUTE               \   .COM FILE
   FILE.PATH -TRAILING " \" "CAT                \
   NAME.FILE "CAT FILE.NAME ":=                 \
   1 CMDAT [ 12 ] :=                            \  ALTER FIRST.LOAD VALUE
   FILE.OPEN DATAFILE.XXX                       \     (SEE GPIB.XXX)
       1 SUBFILE CMDAT ARRAY>FILE               \  SAVE SELECTIONS IN
       FILE.NAME 41 >COMMENT                    \    THE DATA FILE
   FILE.CLOSE                                   \
   LOAD GPIB.XXX ;                              \  RE-LOAD GPIB.XXX

:  CONFIG.STAT                               \ MENU DISPLAY
   14 FOREGROUND                             \
   1 CMDAT [ 11 ] =
      IF 35 10 GOTO.XY ." NO "
      ELSE 35 10 GOTO.XY ." YES" THEN
   12 FOREGROUND   60 1 GOTO.XY ." DATE: " "DATE "TYPE 9 FOREGROUND
   40 16 GOTO.XY ."  USAF PHOTONICS CENTER"
   40 17 GOTO.XY ."  GRIFFIS AIR FORCE BASE"
   40 18 GOTO.XY ."      ROME, NEW YORK"
   10 FOREGROUND   60 21 GOTO.XY ." by Brian DeVaul" 11 FOREGROUND ;

CONFIG.MENU                                  \ MAIN SELECTIONS MENU
   " MENU CONFIGURATIONS" MENU.TITLE         \
   MENU.STATUS CONFIG.STAT
   MENU.BLOW.UP
   1 1 24 78 MENU.SHAPE
   0 11 MENU.COLOR
   MENU.STORE.DISK
   15 MENU.PROMPT.COLOR
   3 15 " RETURN TO MAIN MENU" MENU.ITEM{ MENU.ESCAPE }
   6 15 " DEVICE/PROGRAM SELECTION" MENU.ITEM{ DEVICE.MENU }
   8 15 " GPIB DEVICE CONFIGURATION" MENU.ITEM{ GPIB.D.C }
   10 15 " MOUSE SUPPORT:" MENU.ITEM{ MOUSE.SUPPORT }
   13 15 " SAVE NEW SELECTIONS & REBOOT" MENU.ITEM{ SAVE.PROGRAM.CONFIG }
MENU.END
```

Appendix H - Program: HF8116A.XXX (HP - Signal Generator)

```
\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
\                                                                              \
\                          HP8116A SIGNAL GENERATOR                            \
\                                                                              \
\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\

\ ************************** HP8116A VARIABLES *************************** \

    164 STRING CPS                  \ Current Parameter Settings
    13 STRING HILEV                 \ Hi Level setting
    13 STRING LOLEV                 \ Lo Level setting
    13 STRING AMPLT                 \ Amplitude
    13 STRING OFFSET                \ Offset Value
    3 STRING UNITS                  \ Change Units

    1 INTEGER SCALAR LOCK.OUT       \ Keep track of Local Lock out condition
    33 STRING LOCK.TEXT             \ Text displayed on Lock Out status
    1  LOCK.OUT :=

 TOKEN DATA.SG                      \ Define blank variable SG data
 TOKEN CPSI                         \ Integer Parameter Status array
                                    \ Tokens are used to make use of
                                    \   any expanded memory available

\ ****************** DEFAULT GENERATOR PARAMETERS ********************** \

: RELOAD.HP8116A                    \ RELOAD TOKEN DATA
                                    \ ATTEMPT TO USE EXPANDED MEMORY

  ?EXP.MEM IF   EXP.MEM> DATA.SG  EXP.MEM> CPSI   THEN
  INTEGER DIM[ 5 , 22 ] UNNAMED.ARRAY BECOMES> DATA.SG
  INTEGER DIM[ 164 ]    UNNAMED.ARRAY BECOMES> CPSI

      " M"     UNITS.DISPLAY.SG "[ 1 ] ":=
      " CT"    UNITS.DISPLAY.SG "[ 5 ] ":=
      " T"     UNITS.DISPLAY.SG "[ 9 ] ":=
      " H"     UNITS.DISPLAY.SG "[ 13 ] ":=
      " W"     UNITS.DISPLAY.SG "[ 17 ] ":=
      " L"     UNITS.DISPLAY.SG "[ 21 ] ":=
      " C"     UNITS.DISPLAY.SG "[ 25 ] ":=
      " D"     UNITS.DISPLAY.SG "[ 29 ] ":=
      " A"     UNITS.DISPLAY.SG "[ 33 ] ":=
      " FRQ"   UNITS.DISPLAY.SG "[ 37 ] ":=
      " DTY"   UNITS.DISPLAY.SG "[ 41 ] ":=
      " WID"   UNITS.DISPLAY.SG "[ 45 ] ":=
      " AMP"   UNITS.DISPLAY.SG "[ 49 ] ":=
```

```
" OFS"   UNITS.DISPLAY.SG "[ 53 ] ":=
" HIL"   UNITS.DISPLAY.SG "[ 57 ] ":=
" LOL"   UNITS.DISPLAY.SG "[ 61 ] ":=
" BUR"   UNITS.DISPLAY.SG "[ 65 ] ":=
" RPT"   UNITS.DISPLAY.SG "[ 69 ] ":=
" STA"   UNITS.DISPLAY.SG "[ 73 ] ":=
" STP"   UNITS.DISPLAY.SG "[ 77 ] ":=
" MRK"   UNITS.DISPLAY.SG "[ 81 ] ":=
" SWT"   UNITS.DISPLAY.SG "[ 85 ] ":=

"    1 = NORM : 4 = E.WID : 7 = I.BUR  "   UNITS.DISPLAY.SG "[ 2 ] ":=
"    2 = TRIG : 5 = I.SWP : 8 = E.BUR  "   UNITS.DISPLAY.SG "[ 3 ] ":=
"    3 = GATE : 6 = E.SWP              "   UNITS.DISPLAY.SG "[ 4 ] ":=
"    1 = FM   :   3 = PWM  :   0 = OFF "   UNITS.DISPLAY.SG "[ 6 ] ":=
"                                      "   UNITS.DISPLAY.SG "[ 7 ] ":=
"    2 = AM   :   4 = VCO              "   UNITS.DISPLAY.SG "[ 8 ] ":=
"           0 = OFF                    "   UNITS.DISPLAY.SG "[ 10 ] ":=
"           1 = POSITIVE               "   UNITS.DISPLAY.SG "[ 11 ] ":=
"           2 = NEGATIVE               "   UNITS.DISPLAY.SG "[ 12 ] ":=
"                                      "   UNITS.DISPLAY.SG "[ 14 ] ":=
"       0  =  OFF   :   1  =  ON       "   UNITS.DISPLAY.SG "[ 15 ] ":=
"                                      "   UNITS.DISPLAY.SG "[ 16 ] ":=
"     1 = SINE     : 4 = PULSE         "   UNITS.DISPLAY.SG "[ 18 ] ":=
"     2 = TRIANGLE :                   "   UNITS.DISPLAY.SG "[ 19 ] ":=
"     3 = SQUARE   : 0 = OFF           "   UNITS.DISPLAY.SG "[ 20 ] ":=
"                                      "   UNITS.DISPLAY.SG "[ 22 ] ":=
"       0  =  OFF   :   1  =  ON       "   UNITS.DISPLAY.SG "[ 23 ] ":=
"                                      "   UNITS.DISPLAY.SG "[ 24 ] ":=
"                                      "   UNITS.DISPLAY.SG "[ 26 ] ":=
"       0  =  OFF   :   1  =  ON       "   UNITS.DISPLAY.SG "[ 27 ] ":=
"                                      "   UNITS.DISPLAY.SG "[ 28 ] ":=
"                                      "   UNITS.DISPLAY.SG "[ 30 ] ":=
"       0  =  NO    :   1  =  YES      "   UNITS.DISPLAY.SG "[ 31 ] ":=
"                                      "   UNITS.DISPLAY.SG "[ 32 ] ":=
"                                      "   UNITS.DISPLAY.SG "[ 34 ] ":=
"       0  =  OFF   :   1  =  ON       "   UNITS.DISPLAY.SG "[ 35 ] ":=
"                                      "   UNITS.DISPLAY.SG "[ 36 ] ":=
"   mz = milliHERTZ : kHz = KILOHERTZ  "   UNITS.DISPLAY.SG "[ 38 ] ":=
"                   :                  "   UNITS.DISPLAY.SG "[ 39 ] ":=
"   Hz = HERTZ      : MHz = MEGAHERTZ  "   UNITS.DISPLAY.SG "[ 40 ] ":=
"                                      "   UNITS.DISPLAY.SG "[ 42 ] ":=
"        ENTER CYCLE PERCENTAGE        "   UNITS.DISPLAY.SG "[ 43 ] ":=
"                                      "   UNITS.DISPLAY.SG "[ 44 ] ":=
"           MS = MILLISECONDS          "   UNITS.DISPLAY.SG "[ 46 ] ":=
"           US = MICROSECONDS          "   UNITS.DISPLAY.SG "[ 47 ] ":=
"           NS = NANOSECONDS           "   UNITS.DISPLAY.SG "[ 48 ] ":=
"                                      "   UNITS.DISPLAY.SG "[ 50 ] ":=
"      V = VOLTS   :  MV = MILLIVOLTS  "   UNITS.DISPLAY.SG "[ 51 ] ":=
"                                      "   UNITS.DISPLAY.SG "[ 52 ] ":=
```

```
" IOFS" GW   OFFSET GR

1 LOCK.OUT - IF GEN LISTENER GO.TO.LOCAL  \ ENABLE/DISABLE LOCAL LOCK OUT
          ELSE GEN LISTENER LOCAL.LOCKOUT  THEN

\ *************************** DISPLAY DATA ****************************** \
\
\  SOME PARAMETERS NEED A SECOND STRING, THE NEXT TWO SECTIONS DISPLAY
\  ALL OF THE PARAMETERS PERTAINING TO THE SIGNAL GENERATOR
\
   10 1 DO  DATA.SG [ 1 , I ] DATA.SG [ 2 , I ] GOTO.XY
     CPS DATA.SG [ 3 , I ] 4 "SUB "TYPE  DATA.SG [ 1 , I ] 5 + Z :-
          Z DATA.SG [ 2 , I ] GOTO.XY
     CPS DATA.SG [ 4 , I ] DATA.SG [ 5 , I ] "SUB "TYPE  LOOP

  19 10 DO   CPS DATA.SG [ 3 , I ] 1 "SUB 0 "NUMBER X :-
      I 9 - 6 * 5 - Z :- X 6 < IF Z X + Z :- ELSE 49 X + Z :-
      THEN DATA.SG [ 1 , I ] DATA.SG [ 2 , I ] GOTO.XY CLRSCR 1 10 "SUB
      "TYPE  DATA.SG [ 1 , I ] DATA.SG [ 2 , I ] GOTO.XY
      DATA.TEXT.SG "[ Z ] "TYPE SC
  LOOP
 \                                                                    /
 \ THIS SECTION DISPLAYS MISC. PARAMETERS NOT FOUND IN THE CPS ARRAY /
 \                                                                    /
  65 12 GOTO.XY HILEV 5 8 "SUB "TYPE                  \ HI LEVEL
  65 13 GOTO.XY LOLEV 5 8 "SUB "TYPE                  \ LOW LEVEL
  20 10 GOTO.XY AMPLT 5 8 "SUB "TYPE                  \ AMPLITUDE
  27 10 GOTO.XY AMPLT 12 2 "SUB "TYPE                 \
  20 11 GOTO.XY OFFSET 5 8 "SUB "TYPE                 \ OFFSET

  C5S3 FOREGROUND  42 5 GOTO.XY LOCK.TEXT  "TYPE

;
\
\ **************************** TEXT *************************************** \
\
: HP8116A.STATUS    C5S1 FOREGROUND
  DISPLAY.DATA      C5S2 FOREGROUND
  26 8 GOTO.XY ." CURRENT PARAMETER SETTINGS"
  0 8 GOTO.XY ." ********************"
  58 8 GOTO.XY ." ********************"
  1 10 GOTO.XY ." Amplitude:"       40 10 GOTO.XY ." Output Disabled:"
  1 11 GOTO.XY ." Offset:"          40 11 GOTO.XY ." Autovernier:"
  1 12 GOTO.XY ." Operating Mode:"  40 12 GOTO.XY ." High Level"
  1 13 GOTO.XY ." Control Mode:"    40 13 GOTO.XY ." Low Level:"
  1 14 GOTO.XY ." Trigger Slope:"   40 14 GOTO.XY ." Burst Number:"
  1 15 GOTO.XY ." Haversine(-90):"  40 15 GOTO.XY ." Repetition Rate:"
  1 16 GOTO.XY ." Waveform:"        40 16 GOTO.XY ." Sweep Start Freq.:"
  1 17 GOTO.XY ." Frequency:"       40 17 GOTO.XY ." Sweep Stop Freq.:"
```

```
"                                           "   UNITS.DIS'LAY.SG "[ 54 ] ":=
"       V = VOLTS   :   MV = MILLIVOLTS     "   UNITS.DISPLAY.SG "[ 55 ] ":=
"                                           "   UNITS.DISPLAY.SG "[ 56 ] ":=
"                                           "   UNITS.DISPLAY.SG "[ 58 ] ":=
"         ENTER AMOUNT OF VOLTS             "   UNITS.DISPLAY.SG "[ 59 ] ":=
"                                           "   UNITS.DISPLAY.SG "[ 60 ] ":=
"                                           "   UNITS.DISPLAY.SG "[ 62 ] ":=
"         ENTER AMOUNT OF VOLTS             "   UNITS.DISPLAY.SG "[ 63 ] ":=
"                                           "   UNITS.DISPLAY.SG "[ 64 ] ":=
"                                           "   UNITS.DISPLAY.SG "[ 66 ] ":=
"         ENTER NUMBER OF BURSTS            "   UNITS.DISPLAY.SG "[ 67 ] ":=
"                                           "   UNITS.DISPLAY.SG "[ 68 ] ":=
"                                           "   UNITS.DISPLAY.SG "[ 70 ] ":=
"     ENTER REPETATIVE RATE OF SWEEPS       "   UNITS.DISPLAY.SG "[ 71 ] ":=
"                                           "   UNITS.DISPLAY.SG "[ 72 ] ":=
"    mz = milliHERTZ : kHz = KILOHERTZ      "   UNITS.DISPLAY.SG "[ 74 ] ":=
"                    :                      "   UNITS.DISPLAY.SG "[ 75 ] ":=
"    Hz = HERTZ      : MHz = MEGAHERTZ      "   UNITS.DISPLAY.SG "[ 76 ] ":=
"    mz = milliHERTZ : kHz = KILOHERTZ      "   UNITS.DISPLAY.SG "[ 78 ] ":=
"                    :                      "   UNITS.DISPLAY.SG "[ 79 ] ":=
"    Hz = HERTZ      : MHz = MEGAHERTZ      "   UNITS.DISPLAY.SG "[ 80 ] ":=
"    mz = milliHERTZ : kHz = KILOHERTZ      "   UNITS.DISPLAY.SG "[ 82 ] ":=
"                    :                      "   UNITS.DISPLAY.SG "[ 83 ] ":=
"    Hz = HERTZ      : MHz = MEGAHERTZ      "   UNITS.DISPLAY.SG "[ 84 ] ":=
"                                           "   UNITS.DISPLAY.SG "[ 86 ] ":=
"    S = SECONDS   :   MS = MILLISECONDS    "   UNITS.DISPLAY.SG "[ 87 ] ":=
"                                           "   UNITS.DISPLAY.SG "[ 88 ] ":=

"         " DATA.TEXT.SG "[ 1 ]   ":= "        " DATA.TEXT.SG "[ 29 ]  ":=
" NORM    " DATA.TEXT.SG "[ 2 ]   ":= "        " DATA.TEXT.SG "[ 30 ]  ":=
" TRIG    " DATA.TEXT.SG "[ 3 ]   ":= " OFF    " DATA.TEXT.SG "[ 31 ]  ":=
" GATE    " DATA.TEXT.SG "[ 4 ]   ":= " ON     " DATA.TEXT.SG "[ 32 ]  ":=
" E.WID   " DATA.TEXT.SG "[ 5 ]   ":= "        " DATA.TEXT.SG "[ 33 ]  ":=
" I.SWP   " DATA.TEXT.SG "[ 6 ]   ":= "        " DATA.TEXT.SG "[ 34 ]  ":=
" OFF     " DATA.TEXT.SG "[ 7 ]   ":= "        " DATA.TEXT.SG "[ 35 ]  ":=
" FM      " DATA.TEXT.SG "[ 8 ]   ":= "        " DATA.TEXT.SG "[ 36 ]  ":=
" AM      " DATA.TEXT.SG "[ 9 ]   ":= " OFF    " DATA.TEXT.SG "[ 37 ]  ":=
" PWM     " DATA.TEXT.SG "[ 10 ]  ":= " ON     " DATA.TEXT.SG "[ 38 ]  ":=
" VCO     " DATA.TEXT.SG "[ 11 ]  ":= "        " DATA.TEXT.SG "[ 39 ]  ":=
"         " DATA.TEXT.SG "[ 12 ]  ":= "        " DATA.TEXT.SG "[ 40 ]  ":=
" OFF     " DATA.TEXT.SG "[ 13 ]  ":= "        " DATA.TEXT.SG "[ 41 ]  ":=
" POSITIVE" DATA.TEXT.SG "[ 14 ]  ":= "        " DATA.TEXT.SG "[ 42 ]  ":=
" NEGATIVE" DATA.TEXT.SG "[ 15 ]  ":= " OFF    " DATA.TEXT.SG "[ 43 ]  ":=
"         " DATA.TEXT.SG "[ 16 ]  ":= " ON     " DATA.TEXT.SG "[ 44 ]  ":=
"         " DATA.TEXT.SG "[ 17 ]  ":= "        " DATA.TEXT.SG "[ 45 ]  ":=
"         " DATA.TEXT.SG "[ 18 ]  ":= "        " DATA.TEXT.SG "[ 46 ]  ":=
"         " DATA.TEXT.SG "[ 19 ]  ":= "        " DATA.TEXT.SG "[ 47 ]  ":=
" SINE    " DATA.TEXT.SG "[ 20 ]  ":= "        " DATA.TEXT.SG "[ 48 ]  ":=
" TRIANGLE" DATA.TEXT.SG "[ 21 ]  ":= " NO     " DATA.TEXT.SG "[ 49 ]  ":=
```

```
" SQUARE   " DATA.TEXT.SC "[ 22 ]  ":= " YES     " DATA.TEXT.SG "[ 50 ]  ":=
" PULSE    " DATA.TEXT.SG "[ 23 ]  ":= "         " DATA.TEXT.SG "[ 51 ]  ":=
" OFF      " DATA.TEXT.SG "[ 24 ]  ":= "         " DATA.TEXT.SG "[ 52 ]  ":=
" OFF      " DATA.TEXT.SG "[ 25 ]  ":= "         " DATA.TEXT.SG "[ 53 ]  ":=
" ON       " DATA.TEXT.SG "[ 26 ]  ":= "         " DATA.TEXT.SG "[ 54 ]  ":=
"          " DATA.TEXT.SG "[ 27 ]  ":= " E.SWP   " DATA.TEXT.SG "[ 55 ]  ":=
"          " DATA.TEXT.SG "[ 28 ]  ":= " I.BUR   " DATA.TEXT.SG "[ 56 ]  ":=
                                       " E.BUR   " DATA.TEXT.SG "[ 57 ]  ":=

 DATA.SG @[ 1 , 1 ]                          \ LOAD NUMERIC DATA

 ENTER[ 20 , 20 , 20 , 65 , 65 , 65 , 65 , 65 , 65 , 20 , 20
      , 20 , 20 , 20 , 20 , 65 , 65 , 65 , 65 , 65 , 20 , 20
      , 17 , 18 , 19 , 14 , 15 , 16 , 17 , 18 , 19 , 12 , 13
      , 14 , 16 , 15 , 20 , 20 , 11 , 10 , 12 , 13 , 10 , 11
      , 106 , 119 , 130 , 34 , 46 , 58 , 70 , 94 , 82 , 3 , 7
      , 10 , 13 , 16 , 22 , 25 , 19 , 28 , 8 , 8 , 6 , 8
      , 110 , 124 , 135 , 0 , 51 , 62 , 74 , 98 , 87 , 0 , 0
      , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0
      , 3 , 1 , 2 , 0 , 2 , 3 , 3 , 3 , 2 , 0 , 0
      , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 ]

;

RELOAD.HP8116A                              \ BLANK ARRAYS HAVE TO BE RELOADED
                                            \  EVERY TIME THE PROGRAM IS
                                            \  ENTERED FROM DOS.
\ ****************** DECLARE SIGNAL GENERATOR MENUS ******************** \

     MENU HP8116A.MENU
     MENU SGCP.MENU
     MENU SGDP.MENU
     MENU SGFILE

\ *************** RECEIVE PARAMETER DATA FROM DEVICE ******************** \

: DISPLAY.DATA                              \ DISPLAY PARAMETER SETTINGS

    GEN                  \ CURRENT DEVICE - SIGNAL GENERATOR
    INIT 255 SPD         \ CLAER GPIB BUS AND DROP ALL PREVIOUS ERROR MESSAGES
    " CST" GW            \ COMMAND PARAMETER SETTING DATA BE SENT TO COMPUTER
    CPS GR               \ PUT DATA INTO THE STRING CPS

    CPS 87 1 "SUB " S" "=                   \ QUERY FOR ALL OTHER PARAMETERS
     IF CPS 88 75 "SUB CPS 89 75 "SUB ":= "  " CPS 88 1 "SUB ":=
      DATA.SG [ 5 , 9 ] 1 - DATA.SG [ 5 , 9 ] := THEN
    " IHIL" GW   HILEV GR
    " ILOL" GW   LOLEV GR
    " IAMP" GW   AMPLT GR
```

```
    1 18 GOTO.XY ." Duty Cycle:"      40 18 GOTO.XY ." Sweep Marker Freq.:"
    1 19 GOTO.XY ." Width:"           40 19 GOTO.XY ." Sweep Time:"
    1 20 GOTO.XY ." Limit (on/off):"  40 20 GOTO.XY ." Complement (on/off):"
    C5F FOREGROUND
;

: LOCK.OUT.SWITCH         LOCK.OUT 1 =    \ COLON DEFINITION TO ENABLE/DISABLE
                                          \  LOCAL LOCK OUT

    IF     " INSTRUMENT FRONT PANEL LOCKED-OUT"  LOCK.TEXT ":=
           0 LOCK.OUT := GEN LISTENER LOCAL.LOCKOUT
    ELSE   "     FRONT PANEL OPERATIONAL      "  LOCK.TEXT ":=
           1 LOCK.OUT := GEN LISTENER GO.TO.LOCAL
    THEN  ;

HP8116A.MENU
    MENU.STATUS HP8116A.STATUS
    MENU.BLOW.UP
    1 1 24 79 MENU.SHAPE
    C5B C5F MENU.COLOR
    C5P MENU.PROMPT.COLOR
    1 1 " CHANGE PARAMETERS" MENU.ITEM( SGCP.MENU )
    3 1 " EXECUTE DESIGNED PROGRAMS" MENU.ITEM( SGDP.MENU )
    5 1 " ENABLE / DISABLE FRONT PANEL" MENU.ITEM( LOCK.OUT.SWITCH )
MENU.END

\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
\                                                                          \
\          Design for the Signal Generator Change Parameters Menu          \
\                                                                          \
\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
\
\ THE NEXT TWO SECTIONS ARE SEPARATED BY THEIR ALLOWABLE TYPES OF INPUT.
\ THE FIRST IS FOR PARAMETERS NEEDING A USER DEFINED NUMERIC ENTRY, THE
\ SECOND ALLOWS THE USER TO SELECT BETWEEN THE SIGNAL GENERATOR'S OFFERED
\ CHOICES.
\
: EDIT.PARAMETER.SG.ENTER       CLR.DATA C5IB BACKGROUND CLR.UNITS.DISPLAY
   P 4 * 3 - P :=    1 FOREGROUND 48 2 GOTO.XY ." ENTER A NUMERIC VALUE"
   X.C Y.C GOTO.XY CLRSCR 1 5 "SUB "TYPE X.C Y.C GOTO.XY "INPUT COM.DATA ":=
   4 1 DO I P + Z := 40 I GOTO.XY  UNITS.DISPLAY.SG "[ Z ] "TYPE LOOP
   X.C 7 + X.C :=    X.C Y.C GOTO.XY CLRSCR 1 DATA.L "SUB "TYPE
   X.C Y.C GOTO.XY "INPUT UNITS ":= GEN LISTENER ME TALKER C5B BACKGROUND
   UNITS.DISPLAY.SG "[ P ] COM.DATA "CAT UNITS "CAT COM ":= COM T
   GEN 255 SPD  X.C 7 - X.C :=  CLR.DATA CLR.UNITS.DISPLAY C5F FOREGROUND ;

: EDIT.PARAMETER.SG.CHOICE       C5IF FOREGROUND
   P 4 * 3 - P :=      CLR.DATA C5IB BACKGROUND CLR.UNITS.DISPLAY
   4 1 DO I P + Z := 40 I GOTO.XY  UNITS.DISPLAY.SG "[ Z ] "TYPE LOOP
```

```
X.C Y.C GOTO.XY CLRSCR 1 DATA.L "SUB "TYPE
X.C Y.C GOTO.XY "INPUT COM.DATA ":- GEN LISTENER ME TALKER C5B BACKGROUND
UNITS.DISPLAY.SG "[ P ] COM.DATA "CAT UNITS "CAT COM ":- COM T
GEN 255 SPD  CLR.DATA CLR.UNITS.DISPLAY  "   " UNITS ":- C5F FOREGROUND ;


\ *************************** PARAMETERS ******************************** /
\
\  EACH PARAMETER HAS IT'S OWN COLON DEFINITION FOR THE MENU.ITEM SELECTION
\  AND USES THE DEFINITION TO SET X,Y COORDINATES, DATA LENGTH, PLACE IN
\  DATA ARRAY AND WHICH PARAMETER CHANGING COLON DEFINITION (ENTER OR CHOICE).

: OPMODE        \ ******************************** \    OPERATING MODE
    20 X.C :-   12 COLUMN :-   1 P :-
    12 Y.C :-    1 DATA.L :-   EDIT.PARAMETER.SG.CHOICE ;
: CTM           \ ******************************** \    CONTROL MODE
    20 X.C :-   12 COLUMN :-   2 P .-
    13 Y.C :-    1 DATA.L :-   EDIT.PARAMETER.SG.CHOICE ;
: TS            \ ******************************** \    TRIGGER SLOPE
    20 X.C :-   12 COLUMN :-   3 P :-
    14 Y.C :-    1 DATA.L :-   EDIT.PARAMETER.SG.CHOICE ;
: HAV           \ ******************************** \    HAVERSINE
    20 X.C :-   12 COLUMN :-   4 P :-
    15 Y.C :-    1 DATA.L :-   EDIT.PARAMETER.SG.CHOICE ;
: WAVEFORM      \ ******************************** \
    20 X.C :-   12 COLUMN :-   5 P :-
    16 Y.C :-    1 DATA.L :-   EDIT.PARAMETER.SG.CHOICE ;
: LIMIT         \ ******************************** \
    20 X.C :-   12 COLUMN :-   6 P :-
    20 Y.C :-    1 DATA.L :-   EDIT.PARAMETER.SG.CHOICE ;
: COMPL         \ ******************************** \    COMPLIMENT
    65 X.C :-   12 COLUMN :-   7 P :-
    20 Y.C :-    1 DATA.L :-   EDIT.PARAMETER.SG.CHOICE ;
: DISABLE       \ ******************************** \    DISABLE OUTPUT
    65 X.C :-   12 COLUMN :-   8 P :-
    10 Y.C :-    1 DATA.L :-   EDIT.PARAMETER.SG.CHOICE ;
: AUTO          \ ******************************** \    AUTOVERNIER
    65 X.C :-   12 COLUMN :-   9 P :-
    11 Y.C :-    1 DATA.L :-   EDIT.PARAMETER.SG.CHOICE ;
: FREQ          \ ******************************** \    FREQUENCY
    20 X.C :-   12 COLUMN :-   10 P :-
    17 Y.C :-    3 DATA.L :-   EDIT.PARAMETER.SG.ENTER ;
: DTY.CYCLE     \ ******************************** \    DUTY CYCLE
    20 X.C :-   12 COLUMN :-   11 P :-  " %" UNITS ":-
    18 Y.C :-    4 DATA.L :-   EDIT.PARAMETER.SG.CHOICE ;
: WIDTH         \ ******************************** \    SIGNAL WIDTH
    20 X.C :-   12 COLUMN :-   12 P :-
    19 Y.C :-    2 DATA.L :-   EDIT.PARAMETER.SG.ENTER ;
: AMPL          \ ******************************** \    AMPLITUDE
```

```
      20 X.C :=   12 COLUMN :=   13 P :=
      10 Y.C :=    2 DATA.L :=   EDIT.PARAMETER.SG.ENTER ;
: OFST          \ ******************************** \    OFFSET
      20 X.C :=   12 COLUMN :=   14 P :=
      11 Y.C :=    2 DATA.L :=   EDIT.PARAMETER.SG.ENTER ;
: HILL          \ ******************************** \    HIGH LEVEL
      65 X.C :=   12 COLUMN :=   15 P :=  " V" UNITS ":=
      12 Y.C :=    4 DATA.L :=   EDIT.PARAMETER.SG.CHOICE ;
: LOLL          \ ******************************** \    LOW LEVEL
      65 X.C :=   12 COLUMN :=   16 P :=  " V" UNITS ":=
      13 Y.C :=    4 DATA.L :=   EDIT.PARAMETER.SG.CHOICE ;
: BURST#        \ ******************************** \    BURST NUMBER
      65 X.C :=   12 COLUMN :=   17 P :=  " #" UNITS ":=
      14 Y.C :=    4 DATA.L :=   EDIT.PARAMETER.SG.CHOICE ;
: REP.RAT       \ ******************************** \    REPETITION RATE
      65 X.C :=   12 COLUMN :=   18 P :=
      15 Y.C :=    2 DATA.L :=   EDIT.PARAMETER.SG.ENTER ;
: SWPST.FREQ    \ ******************************** \    SWEEP START FREQUENCY
      65 X.C :=   12 COLUMN :=   19 P :=
      16 Y.C :=    3 DATA.L :=   EDIT.PARAMETER.SG.ENTER ;
: SWPSTOP.FREQ  \ ******************************** \    SWEEP STOP FREQUENCY
      65 X.C :=   12 COLUMN :=   20 P :=
      17 Y.C :=    3 DATA.L :=   EDIT.PARAMETER.SG.ENTER ;
: SWPMRK.FREQ   \ ******************************** \    SWEEP MARKER FREQUENCY
      65 X.C :=   12 COLUMN :=   21 P :=
      18 Y.C :=    3 DATA.L :=   EDIT.PARAMETER.SG.ENTER ;
: SWPTIME       \ ******************************** \    SWEEP TIME
      65 X.C :=   12 COLUMN :=   22 P :=
      19 Y.C :=    2 DATA.L :=   EDIT.PARAMETER.SG.ENTER ;

\ **************** SIGNAL GENERATOR PARAMETERS MENU ********************* /

: SGCP.STAT    C5S4 FOREGROUND           \ CHANGE PARAMETERS MENU DISPLAY
    1 1 GOTO.XY ." CHANGE PARAMETERS"
    1 3 GOTO.XY ." EXECUTE DESIGNED PROGRAMS"
    1 5 GOTO.XY ." ENABLE / DISABLE FRONT PANEL"
    26 8 GOTO.XY ." CURRENT PARAMETER SETTINGS"
    0 8 GOTO.XY ." ********************"
    58 8 GOTO.XY ." ********************"
    13 FOREGROUND  DISPLAY.DATA   11 FOREGROUND "   " UNITS ":= ;

SGCP.MENU                                \ CHANGE PARAMETERS MENU
    MENU.STATUS SGCP.STAT
    1 1 24 79 MENU.SHAPE
    C5B C5F MENU.COLOR
    C5P MENU.PROMPT.COLOR
    10 1 " Amplitude:" MENU.ITEM( AMPL )
    11 1 " Offset:" MENU.ITEM( OFST )
    12 1 " Operating Mode:" MENU.ITEM( OPMODE )
```

```
    13 1 " Control Mode:" MENU.ITEM( CTM )
    14 1 " Trigger Slope:" MENU.ITEM( TS )
    15 1 " Haversine(-90):" MENU.ITEM( HAV )
    16 1 " Waveform:" MENU.ITEM( WAVEFORM )
    17 1 " Frequency:" MENU.ITEM( FREQ )
    18 1 " Duty Cycle:" MENU.ITEM( DTY.CYCLE )
    19 1 " Width:" MENU.ITEM( WIDTH )
    20 1 " Limit (on/off):" MENU.ITEM( LIMIT )
    10 40 " Output Disabled:" MENU.ITEM( DISABLE )
    11 40 " Autovernier:" MENU.ITEM  AUTO )
    12 40 " High Level" MENU.ITEM( HILL )
    13 40 " Low Level:" MENU.ITEM( LOLL )
    14 40 " Burst Number:" MENU.ITEM( BURST# )
    15 40 " Repetition Rate:" MENU.ITEM( REP.RAT )
    16 40 " Sweep Start Freq.:" MENU.ITEM( SWPST.FREQ )
    17 40 " Sweep Stop Freq.:" MENU.ITEM( SWPSTOP.FREQ )
    18 40 " Sweep Marker Freq.:" MENU.ITEM( SWPMRK.FREQ )
    19 40 " Sweep Time:" MENU.ITEM( SWPTIME )
    20 40 " Complement (on/off):" MENU.ITEM( COMPL )
MENU.END

\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
\                                                                     \
\                  Execute Specific Parameter Changes                 \
\                                                                     \
\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\


: SCS                                   \ SAVE CURRENT SETTINGS
    SAVE.RESTORE.MENU MENU.EXECUTE      \ CHOOSE FILE NAME
    FILE.PATH " \" "CAT NAME.FILE "CAT  \
    FILE.NAME ":=                       \
    CPS CPSI ">ARRAY                    \ CONVERT STRING TO INTEGER FORMAT
    FILE.TEMPLATE                       \
        INTEGER DIM[ 164 ] SUBFILE      \ CREATE FILE
    END                                 \
    FILE.NAME DEFER> FILE.CREATE        \
    FILE.NAME DEFER> FILE.OPEN          \
    1 SUBFILE CPSI ARRAY>FILE           \  INPUT ARRAY DATA INTO FILE
    FILE.CLOSE MENU.ESCAPE   ;          \


: RSS                                   \ RESTORE SAVED SETTINGS
    SAVE.RESTORE.MENU MENU.EXECUTE      \ CHOOSE FILE NAME
    FILE.PATH " \" "CAT NAME.FILE "CAT  \
    FILE.NAME ":=                       \
    FILE.NAME DEFER> FILE.OPEN          \
    1 SUBFILE CPSI FILE>ARRAY           \ DUMP FILE DATA INTO INTEGER ARRAY
    FILE.CLOSE                          \
```

```
    CPSI CPS ARRAY>"                     \ CONVERT INTEGER ARRAY INTO STRING
    GEN                                  \
    CPS 2 164 "SUB GW                    \ SEND STRING TO SIGNAL GENERATOR
    255 SPD 5 CUT :-                     \   TO RESTORE SAVED PARAMETERS
    MENU.ESCAPE  ;                       \

SGDP.MENU                                \ SAVE & RESTORE PARAMETERS MENU
    2 50 6 76 MENU.SHAPE
    CS1B CS1F MENU.COLOR
    CS1P MENU.PROMPT.COLOR
    1 2 " GO TO THE O.K. PROMPT" MENU.ITEM( OKP )
    2 2 " SAVE CURRENT SETTINGS" MENU.ITEM( SCS )
    3 2 " READ SAVED SETTINGS" MENU.ITEM( RSS )
MENU.END
```

Appendix I - Program: ITHACO.XXX (ITHACO - Lock-in Amplifier)

```
\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\ \
\                                                                        \
\        ITHACO 385EO DUAL CHANNEL INTEGRATOR/COUPLER with               \
\         an ITHACO 397EO LOCK-IN AMPLIFIER                              \
\                                                                        \
\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\ \

\ ***************************  Defining Variables  ************************ /

  INTEGER SCALAR NT     11 NT :=              \ NUMBER OF TIMES EXECUTED
  INTEGER DIM[ 6 ]    ARRAY ST                \
  INTEGER DIM[ 100 ] ARRAY CPSI.385           \ INTEGER PARAMETER STRING
  REAL DIM[ 10 ] ARRAY AN   AN []RAMP         \ SIGNAL  A
  REAL DIM[ 10 ] ARRAY BN   BN []RAMP         \ SIGNAL  B

  DIM[ 10 , 70 ] STRING.ARRAY RAW.DATA.385        6 STRING FS.P
  DIM[ 10 , 9 ]  STRING.ARRAY A                   6 STRING BW.P
  DIM[ 10 , 9 ]  STRING.ARRAY B                   6 STRING DM.P
  DIM[ 10 , 9 ]  STRING.ARRAY AB                  6 STRING EX.P
  DIM[ 10 , 6 ]  STRING.ARRAY PHASE               6 STRING GC.P
  DIM[ 10 , 9 ]  STRING.ARRAY A+B                 6 STRING IL.P
  DIM[ 10 , 9 ]  STRING.ARRAY A-B                 6 STRING DF.P
  DIM[ 10 , 12 ] STRING.ARRAY A/B                 6 STRING OM.P
  10 STRING D1       10 STRING D4                 6 STRING AD.P
  10 STRING D2       10 STRING D5                 6 STRING SR.P
  10 STRING D3       10 STRING D6                 6 STRING TRIG.P
 100 STRING CPS.385                               6 STRING BASE.P

  TOKEN DATA.385

: RELOAD.ITHACO
  ?EXP.MEM IF  EXP.MEM> DATA.385 THEN
  INTEGER DIM[ 5 , 22 ] UNNAMED.ARRAY BECOMES> DATA.385
  DATA.385 []RAMP

      " A"     UNITS.DISPLAY.385 "[ 1 ] ":=
      " B"     UNITS.DISPLAY.385 "[ 5 ] ":=
      " I"     UNITS.DISPLAY.385 "[ 9 ] ":=
      " R"     UNITS.DISPLAY.385 "[ 13 ] ":=
      " T"     UNITS.DISPLAY.385 "[ 17 ] ":=
      " O"     UNITS.DISPLAY.385 "[ 21 ] ":=
      " E"     UNITS.DISPLAY.385 "[ 25 ] ":=
      " G"     UNITS.DISPLAY.385 "[ 29 ] ":=

    "   0 - 1 Volt Full Scale Sensitivity  "   UNITS.DISPLAY.385 "[ 2 ] ":=
    "                                      "   UNITS.DISPLAY.385 "[ 3 ] ":=
```

```
"  1 - 10 Volts Full Scale Sensitivity "   UNITS.DISPLAY.385 "[ 4 ] ":-
"        0  -  2  Hertz                 "   UNITS.DISPLAY.385 "[ 6 ] ":-
"                                       "   UNITS.DISPLAY.385 "[ 7 ] ":-
"        1  -  20 Hertz                 "   UNITS.DISPLAY.385 "[ 8 ] ":-
"    Enter the Integration Length       "   UNITS.DISPLAY.385 "[ 10 ] ":-
"                                       "   UNITS.DISPLAY.385 "[ 11 ] ":-
"     in  1/60 second increments        "   UNITS.DISPLAY.385 "[ 12 ] ":-
"     Enter the Autorange Delay         "   UNITS.DISPLAY.385 "[ 14 ] ":-
"                                       "   UNITS.DISPLAY.385 "[ 15 ] ":-
"     in  1/60 second increments        "   UNITS.DISPLAY.385 "[ 16 ] ":-
"      T - TTL Triggering Input         "   UNITS.DISPLAY.385 "[ 18 ] ":-
"      B - GPIB Triggering              "   UNITS.DISPLAY.385 "[ 19 ] ":-
"   I - INTERNAL : E - EXTERNAL(T & B)  "   UNITS.DISPLAY.385 "[ 20 ] ":-
"                                       "   UNITS.DISPLAY.385 "[ 22 ] ":-
"      C - Continuous  : B - Burst      "   UNITS.DISPLAY.385 "[ 23 ] ":-
"                                       "   UNITS.DISPLAY.385 "[ 24 ] ":-
"         0  -  No Expansion            "   UNITS.DISPLAY.385 "[ 26 ] ":-
"                                       "   UNITS.DISPLAY.385 "[ 27 ] ":-
"        1  -  Expansion  x 10          "   UNITS.DISPLAY.385 "[ 28 ] ":-
"   0 - Off     : 3 - 1 mV   : 6 - 1 V  "   UNITS.DISPLAY.385 "[ 30 ] ":-
"   1 - 10 uV   : 4 - 10 mV  :          "   UNITS.DISPLAY.385 "[ 31 ] ":-
"   2 - 100 uV  : 5 - 100 mV : 7 - Off  "   UNITS.DISPLAY.385 "[ 32 ] ":-

"                  " DATA.TEXT.385 "[ 1 ]  ":-
"                  " DATA.TEXT.385 "[ 2 ]  ":-
"                  " DATA.TEXT.385 "[ 3 ]  ":-
"                  " DATA.TEXT.385 "[ 4 ]  ":-
"                  " DATA.TEXT.385 "[ 5 ]  ":-
"                  " DATA.TEXT.385 "[ 6 ]  ":-
"                  " DATA.TEXT.385 "[ 7 ]  ":-
"                  " DATA.TEXT.385 "[ 8 ]  ":-
"                  " DATA.TEXT.385 "[ 9 ]  ":-
"                  " DATA.TEXT.385 "[ 10 ] ":-
"                  " DATA.TEXT.385 "[ 11 ] ":-
"                  " DATA.TEXT.385 "[ 12 ] ":-
"                  " DATA.TEXT.385 "[ 13 ] ":-
"                  " DATA.TEXT.385 "[ 14 ] ":-
"                  " DATA.TEXT.385 "[ 15 ] ":-
"                  " DATA.TEXT.385 "[ 16 ] ":-
"                  " DATA.TEXT.385 "[ 17 ] " -
"                  " DATA.TEXT.385 "[ 18 ] ":-
"                  " DATA.TEXT.385 "[ 19 ] ":-
"                  " DATA.TEXT.385 "[ 20 ] ":-
"                  " DATA.TEXT.385 "[ 21 ] ":-
"                  " DATA.TEXT.385 "[ 22 ] ":-
"                  " DATA.TEXT.385 "[ 23 ] ":-
"                  " DATA.TEXT.385 "[ 24 ] ":-
"                  " DATA.TEXT.385 "[ 25 ] ":-
"                  " DATA.TEXT.385 "[ 26 ] ":-
```

```
"                   " DATA.TEXT.385 "[ 27 ] ":-
"                   " DATA.TEXT.385 "[ 28 ] ":-

" A       " DATA.FORMAT "[ 1 ]    ":-
" B       " DATA.FORMAT "[ 2 ]    ":-
" VS & PA" DATA.FORMAT "[ 3 ]    ":-
" A+B     " DATA.FORMAT "[ 4 ]    ":-
" A-B     " DATA.FORMAT "[ 5 ]    ":-
" A/B     " DATA.FORMAT "[ 6 ]    ":-

;
RELOAD.ITHACO

\ *************************** Defining Menus *************************** /

                              MENU ITHACO.MENU
                              MENU ITHACO.MENU2
                              MENU ITHACO.MENU3
                              MENU ITHACO.MENU4
                              MENU ITHACO.MENU5
                              MENU ITHACO.MENU6
                              MENU DF.MENU.385

\ ***************** RECEIVE PARAMETER DATA FROM DEVICE ******************** /

: RECEIVE.DATA.385
    ITH385                  \ CURRENT DEVICE - ITHACO 385EO
    50 MSEC.DELAY
    255 SPD
    " ?",GW                 \ SEND PARAMETER SETTING DATA TO COMPUTER
    CPS.385 GR              \ PUT DATA INTO THE PARAMETER STRING
;
: DISPLAY.DATA.385

    RECEIVE.DATA.385

 \ **************************** DISPLAY DATA ***************************** /
                                                        \
    CPS.385 2 1 "SUB FS.P ":-                           \   FULL SCALE
    FS.P " 0" "= IF 20 14 GOTO.XY ." 1" THEN            \   SENSITIVITY
    FS.P " 1" "= IF 20 14 GOTO.XY ." 10" THEN           \
    23 14 GOTO.XY ." Volt Full Scale"

    CPS.385 5 1 "SUB BW.P ":-                           \   BANDWIDTH
    BW.P " 0" "= IF 20 15 GOTO.       2" THEN           \     x100
    BW.P " 1" "= IF 20 15 GOTO.      20" THEN           \
    27 15 GOTO.XY ." Hertz"

    CPS.385 18 4 "SUB 0 "NUMBER                       \ INTEGRATION LENGTH
```

```
    20 16 GOTO.XY .                                          \
    27 16 GOTO.XY ." 1/60 SEC"                               \

    CPS.385 30 3 "SUB 0 "NUMBER                               \ AUTORANGE DELAY
    20 17 GOTO.XY .                                           \
    27 17 GOTO.XY ." 1/60 SEC"                                \

    CPS.385 27 1 "SUB OM.P ":-                                \  OUTPUT MODE
    OM.P " C" "- IF 55 15 GOTO.XY ." Continuous" THEN         \
    OM.P " B" "- IF 55 15 GOTO.XY ." Burst" THEN              \

    CPS.385 39 1 "SUB TRIG.P ":-                              \  TRIGGER MODE
     TRIG.P " I" "- IF 55 14 GOTO.XY ." Trigger Internally"    THEN \
     TRIG.P " T" "- IF 55 14 GOTO.XY ." TTL Trig Input "       THEN \
     TRIG.P " B" "- IF 55 14 GOTO.XY ." GPIB Triggering"       THEN \
     TRIG.P " E" "- IF 55 14 GOTO.XY ." External TT + TB Mode" THEN \

    CPS.385 42 1 "SUB BASE.P ":-                          \ BASELINE CORRECTION
     BASE.P  " 0" "- IF 46 20 GOTO.XY ."               " THEN \
     BASE.P  " 1" "- IF 46 20 GOTO.XY ." Baseline Corr." THEN \
     BASE.P  " 2" "- IF 46 21 GOTO.XY ." Error         " THEN \
     BASE.P  " 3" "- IF 61 20 GOTO.XY ." Read to Host  " THEN \
     BASE.P  " 4" "- IF 61 21 GOTO.XY ." Send from Host" THEN \

    CPS.385 12 1 "SUB EX.P ":-                                \  EXPANSION
    EX.P " 0" "- IF 55 16 GOTO.XY ." No Expansion" THEN       \
    EX.P " 1" "- IF 55 16 GOTO.XY ." Expansion x10" THEN      \

    CPS.385 15 1 "SUB GC.P ":-                                \  GAIN CONTROL
       GC.P " 1" "- IF 55 17 GOTO.XY ." 10 u Volts " THEN     \
       GC.P " 2" "- IF 55 17 GOTO.XY ." 100 u Volts" THEN     \
       GC.P " 3" "- IF 55 17 GOTO.XY ." 1 m Volts  " THEN     \
       GC.P " 4" "- IF 55 17 GOTO.XY ." 10 m Volts " THEN     \
       GC.P " 5" "- IF 55 17 GOTO.XY ." 100 m Volts" THEN     \
       GC.P " 6" "- IF 55 17 GOTO.XY ." 1 Volts    " THEN     \
       GC.P " 7" "- IF 55 17 GOTO.XY ." OFF        " THEN     \
       GC.P " 0" "- IF 55 17 GOTO.XY ." OFF        " THEN     \
  ;

  : CLEAR.DISPLAY.DF
    CLRSCR "TYPE CLRSCR 1 5 "SUB "TYPE ;

  : DISPLAY.DF              \ DISPLAY DATA FORMAT
    CPS.385 8 2 "SUB 0 "NUMBER X :-
    X Y :-
    X 0 <> IF
     X 32 >- IF DATA.FORMAT "[ 6 ] D6 ":- X 32 - X :- ELSE "  " D6 ":- THEN
     X 16 >- IF DATA.FORMAT "[ 5 ] D5 ":- X 16 - X :- ELSE "  " D5 ":- THEN
     X  8 >- IF DATA.FORMAT "[ 4 ] D4 ":- X  8 - X :- ELSE "  " D4 ":- THEN
```

```
   X  4 >= IF DATA.FORMAT "[ 3 ] D3 ":= X  4 - X := ELSE "   " D3 ":= THEN
   X  2 >= IF DATA.FORMAT "[ 2 ] D2 ":= X  2 - X := ELSE "   " D2 ":= THEN
   X  1 >= IF DATA.FORMAT "[ 1 ] D1 ":= X  1 - X := ELSE "   " D1 ":= THEN
      " Data Format: " D1 "CAT D2 "CAT D3 "CAT D4 "CAT D5 "CAT D6 "CAT
      "TYPE Y X :=
   THEN
;

\ ****************************** TEXT ************************************ /

: ITHACO.STATUS1
   DISPLAY.DATA.385 1 19 GOTO.XY CLEAR.DISPLAY.DF
   1 19 GOTO.XY DISPLAY.DF
   26 12 GOTO.XY ." CURRENT PARAMETER SETTINGS"
   1 12 GOTO.XY ." ********************"
   58 12 GOTO.XY ." ********************"
   1 14 GOTO.XY ." Sensitivity:"
   1 15 GOTO.XY ." Bandwidth:"
   1 16 GOTO.XY ." Integration Size:"
   1 17 GOTO.XY ." Autorange Delay:"
   40 14 GOTO.XY ." Trigger Mode:"
   40 15 GOTO.XY ." Output Mode:"
   40 16 GOTO.XY ." Expansion:"
   40 17 GOTO.XY ." Gain Control:"
;

: O.K
   MENU.ESCAPE MENU.ESCAPE
;

ITHACO.MENU
    MENU.STATUS ITHACO.STATUS1
    " ITHACO 385EO MAIN MENU" MENU.TITLE
    MENU.BLOW.UP
    1 1 25 78 MENU.SHAPE
    0 3 MENU.COLOR
    15 MENU.PROMPT.COLOR
    1 1 " CHANGE PARAMETERS" MENU.ITEM( ITHACO.MENU2 )
    3 1 " RECEIVE AND SHOW DATA" MENU.ITEM( ITHACO.MENU3 )
    5 1 " READ/SAVE PARAMETER SETTINGS" MENU.ITEM( ITHACO.MENU4 )
    7 1 " EXIT TO 'OK' PROMPT" MENU.ITEM( O.K )
    9 1 " RETURN TO MAIN MENU" MENU.ITEM( MENU.ESCAPE )
MENU.END

\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
\                                                                            \
\                        CHANGE PARAMETER SETTINGS                           \
\                                                                            \
\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
```

```
: EDIT.PARAMETER.385          P 4 * 3 - P :=
    CLR.DATA 12 BACKGROUND CLR.UNITS.DISPLAY
    7 4 DO I P + 3 - Z := 40 I GOTO.XY UNITS.DISPLAY.385 "[ Z ] "TYPE LOOP
    X.C Y.C GOTO.XY CLRSCR 1 DATA.L "SUB "TYPE
    X.C Y.C GOTO.XY "INPUT COM.DATA ":=
    ITH385 LISTENER ME TALKER 0 BACKGROUND
    UNITS.DISPLAY.385 "[ P ] COM.DATA "CAT COM ":= COM T
    CLR.DATA CLR.UNITS.DISPLAY  ;


: FS       \ CHANGE FULL SCALE SENSITIVITY
    20 X.C :=   18 COLUMN :=   1 P .=
    14 Y.C :=    1 DATA.L :=   EDIT.PARAMETER.385 ;

: BW       \ CHANGE BANDWIDTH
    20 X.C :=   18 COLUMN :=   2 P :=
    15 Y.C :=    1 DATA.L :=   EDIT.PARAMETER.385 ;

: IL       \ CHANGE INTEGRATION LENGTH
    20 X.C :=   18 COLUMN :=   3 P :=
    16 Y.C :=    4 DATA.L :=   EDIT.PARAMETER.385 ;

: AD       \ CHANGE AUTORANGE DELAY
    20 X.C :=   18 COLUMN :=   4 P :=
    17 Y.C :=    4 DATA.L :=   EDIT.PARAMETER.385 ;

: TM       \ CHANGE TRIGGER MODE
    55 X.C :=   24 COLUMN :=   5 P :=
    14 Y.C :=    1 DATA.L :=   EDIT.PARAMETER.385 ;

: OM       \ CHANGE OUTPUT MODE
    55 X.C :=   24 COLUMN :=   6 P :=
    15 Y.C :=    1 DATA.L :=   EDIT.PARAMETER.385 ;

: EX       \ EXPANSION MODE
    55 X.C :=   24 COLUMN :=   7 P :=
    16 Y.C :=    1 DATA.L :=   EDIT.PARAMETER.385 ;

: GC       \ CHANGE GAIN CONTROL
    55 X.C :=   24 COLUMN :=   8 P :=
    17 Y.C :=    1 DATA.L :=   EDIT.PARAMETER.385 ;


: EDIT.DATA.FORMAT            DF DATA.FORMAT "[ D ] "=
    IF X Z - X := CLRSCR 1 10 "SUB DF ":=
    ELSE X Z + X := THEN " D" X "." "CAT COM.DATA ":= COM.DATA GW ;

: D1.385 SC 1  Z := 1 D := D1 DF ":= EDIT.DATA.FORMAT DF D1 ":= ;
```

```
: D2.385 SC 2  Z := 2 D := D2 DF ":= EDIT.DATA.FORMAT DF D2 ":= ;
: D3.385 SC 4  Z := 3 D := D3 DF ":= EDIT.DATA.FORMAT DF D3 ":= ;
: D4.385 SC 8  Z := 4 D := D4 DF ":= EDIT.DATA.FORMAT DF D4 ":= ;
: D5.385 SC 16 Z := 5 D := D5 DF ":= EDIT.DATA.FORMAT DF D5 ":= ;
: D6.385 SC 32 Z := 6 D := D6 DF ":= EDIT.DATA.FORMAT DF D6 ":= ;

: DF.STATUS.385
    RECEIVE.DATA.385 SC
    1 9 GOTO.XY CLEAR.DISPLAY.DF 3 FOREGROUND
    1 9 GOTO.XY DISPLAY.DF 4 FOREGROUND
;

DF.MENU.385
     MENU.STATUS DF.STATUS.385
     " SELECT DATA FORMATS" MENU.TITLE
     2 34 11 77 MENU.SHAPE
     0 4 MENU.COLOR
     14 MENU.PROMPT.COLOR
     1 1 "  Channel A " MENU.ITEM{ D1.385 }
     2 1 "  Channel B " MENU.ITEM{ D2.385 }
     3 1 "  Vector Sum & Phase Angle " MENU.ITEM{ D3.385 }
     4 1 "  A + B  " MENU.ITEM{ D4.385 }
     5 1 "  A - B  " MENU.ITEM{ D5.385 }
     6 1 "  A / B  " MENU.ITEM{ D6.385 }
MENU.END

: ITHACO.STATUS2
    DISPLAY.DATA.385 1 19 GOTO.XY CLEAR.DISPLAY.DF
    1 19 GOTO.XY DISPLAY.DF
    26 12 GOTO.XY ." CURRENT PARAMETER SETTINGS"
    1 12 GOTO.XY ." ********************"
    58 12 GOTO.XY ." ********************"
    1 1 GOTO.XY ." CHANGE PARAMETERS"
    1 3 GOTO.XY ." RECEIVE AND SHOW DATA"
    1 5 GOTO.XY ." READ/SAVE PARAMETER SETTINGS"
    1 7 GOTO.XY ." EXIT TO 'OK' PROMPT"
    1 9 GOTO.XY ." RETURN TO MAIN MENU"
;

ITHACO.MENU2
     MENU.STATUS ITHACO.STATUS2
     " ITHACO 385EO MAIN MENU" MENU.TITLE
     1 1 26 78 MENU.SHAPE
     0 3 MENU.COLOR
     15 MENU.PROMPT.COLOR
     14  1 " Sensitivity:" MENU.IT' , FS }
     15  1 " Bandwidth:" MENU.ITEM{ BW }
     16  1 " Integration Size:" MENU.ITEM{ IL }
     17  1 " Autorange Delay:" MENU.ITEM{ AD }
```

```
     19  1 " Data Format:" MENU.ITEM( DF.MENU.385 )
     14 40 " Trigger Mode:" MENU.ITEM( TM )
     15 40 " Output Mode:" MENU.ITEM( OM )
     16 40 " Expansion:" MENU.ITEM( EX )
     17 40 " Gain Control:" MENU.ITEM( GC )
MENU.END


\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
\                                                                            \
\                        GRAPH DATA FROM THE AMPLIFIER                       \
\                                                                            \
\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\

: CHANGE.NT.385
   1 21 GOTO.XY ." INPUT NUMBER OF TEST DATA ( 1 - 10 ): " "INPUT NTS ":=
   NTS 32 "NUMBER NT := 1 NT + NT :=
   17 NT < IF ." TOO HIGH " 17 NT := THEN
   2 NT > IF ." TOO LOW  " 2 NT := THEN
   1 21 GOTO.XY CLRSCR "TYPE CLRSCR "TYPE
;

: INIT.TEST.385
   CPS.385 8 2 "SUB 0 "NUMBER X :=
   0 AOD := X Y :=
   X 0 <> IF
       X 32 >= IF 13 AOD := X 32 - X := THEN
       X 16 >= IF 10 AOD + AOD := X 16 -  X := THEN
       X 8 >= IF 10 AOD + AOD := X 8 - X := THEN
       X 4 >= IF 17 AOD + AOD := X 4 - X := THEN
       X 2 >= IF 10 AOD + AOD := X 2 - X := THEN
       X 1 >= IF 10 AOD + AOD := X 1 - X := THEN
   THEN
;

: CLEAR.TEST.DISPLAY.385
     22 2 DO
       1 I GOTO.XY CLRSCR "TYPE
       37 I GOTO.XY CLRSCR "TYPE
       72 I GOTO.XY CLRSCR 1 4 "SUB "TYPE
     LOOP
;

: TEST.385
\     CLEAR.TEST.DISPLAY.385
      ITH385
     " TI" GW
     NT 1 DO
      RAW.DATA.385 "[ I ] GR
```

```
      LOOP
      " TE" GW
;

: CONVERT.385
      1 AOD + AOD :=
         7 1 DO
           100 ST [ I ] :=
         LOOP
      Y X :=
      X 0 <> IF
          X 32 >= IF AOD 13 - AOD := AOD ST [ 1 ] := X 32 - X := THEN
          X 16 >= IF AOD 10 - AOD := AOD ST [ 2 ] := X 16 - X := THEN
          X 8 >= IF AOD 10 - AOD := AOD ST [ 3 ] := X 8 - X := THEN
          X 4 >= IF AOD 17 - AOD := AOD ST [ 4 ] := X 4 - X := THEN
          X 2 >= IF AOD 10 - AOD := AOD ST [ 5 ] := X 2 - X := THEN
          X 1 >= IF AOD 10 - AOD := AOD ST [ 6 ] := X 1 - X := THEN
      THEN
     NT 1 DO
         100 ST [ 1 ] = IF "     N A" A/B "[ I ] ":= ELSE
         RAW.DATA.385 "[ I ] ST [ 1 ] 13 "SUB A/B "[ I ] ":= THEN
         100 ST [ 2 ] = IF "    N A" A-B "[ I ] ":= ELSE
         RAW.DATA.385 "[ I ] ST [ 2 ] 10 "SUB A-B "[ I ] ":= THEN
         100 ST [ 3 ] = IF "  . N A" A+B "[ I ] ":= ELSE
         RAW.DATA.385 "[ I ] ST [ 3 ] 10 "SUB A+B "[ I ] ":= THEN
         100 ST [ 4 ] = IF "   N A" PHASE "[ I ] ":= "     N A" AB "[ I ] ":=
         ELSE RAW.DATA.395 "[ I ] ST [ 4 ] 10 + 7 "SUB PHASE "[ I ] ":=
              RAW.DATA.385 "[ I ] ST [ 4 ] 10 'SUB AB "[ I ] ":= THEN
         100 ST [ 5 ] = IF "   N A" B "[ I ] ":= ELSE
         RAW.DATA.385 "[ I ] ST [ 5 ] 10 "SUB B "[ I ] ":=
         B "[ I ] 0 "NUMBER REAL BN [ I ] := STACK.CLEAR  THEN
         100 ST [ 6 ] = IF "   N A" A "[ I ] ":= ELSE
         RAW.DATA.385 "[ I ] ST [ 6 ] 10 "SUB A "[ I ] ":=
         A "[ I ] 0 "NUMBER REAL AN [ I ] :=  STACK.CLEAR  THEN
     LOOP
;

: SHOW.DATA.385     5 YC :=
     NT 1 DO
         1 YC GOTO.XY A "[ I ] "TYPE
         12 YC GOTO.XY B "[ I ] "TYPE
         23 YC GOTO.XY AB "[ I ] "TYPE
         34 YC GOTO.XY PHASE "[ I ] "TYPE
         42 YC GOTO.XY A+B "[ I ] "TYPE
         53 YC GOTO.XY A-B "[ I ] "TYPE
         64 YC GOTO.XY A/B "[ I ] "TYPE
         1 YC + YC :=
     LOOP
;
```

```
: DISPLAY.TEST.RESULTS
    4 FOREGROUND
    INIT.TEST.385
    TEST.385
    CONVERT.385
    3 3 GOTO.XY ." CHAN A" 14 3 GOTO.XY ." CHAN B" 23 3 GOTO.XY ." VECTOR SUM"
    35 3 GOTO.XY ." PHASE" 44 3 GOTO.XY ." A + B"  54 3 GOTO.XY ."  A - B"
    68 3 GOTO.XY ." A/B"
    1 FOREGROUND
    SHOW.DATA.385
    3 FOREGROUND
;

\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
\                                                                         \
\                  Execute Specific Parameter Changes                     \
\                                                                         \
\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\

: SCS.385                                  \ SAVE CURRENT SETTINGS
    SAVE.RESTORE.MENU MENU.EXECUTE         \         IN
    CPS.385 CPSI.385 ">ARRAY               \    ASYST FORMAT
    FILE.TEMPLATE                          \
        INTEGER DIM[ 100 ] SUBFILE         \
    END                                    \
    FILE.NAME DEFER> FILE.CREATE           \
    FILE.NAME DEFER> FILE.OPEN             \
    1 SUBFILE CPSI.385 ARRAY>FILE          \
    FILE.CLOSE     MENU.ESCAPE   ;         \


: RSS.385                                  \ RESTORE SAVED SETTINGS
    SAVE.RESTORE.MENU MENU.EXECUTE         \         IN
    FILE.NAME DEFER> FILE.OPEN             \    ASYST FORMAT
    1 SUBFILE CPSI.385 FILE>ARRAY          \
    FILE.CLOSE                             \
    CPSI.385 CPS.385 ARRAY>"               \
    ITH385                                 \
    CPS.385 1 164 "SUB GW                  \
    255 SPD 5 CUT :-                       \
    MENU.ESCAPE  ;                         \

ITHACO.MENU4
    2 50 6 76 MENU.SHAPE
    3 0 MENU.COLOR
    14 MENU.PROMPT.COLOR
    1 2 " GO TO THE O.K. PROMPT" MENU.ITEM( OKP )
```

```
    2 2 " SAVE CURRENT SETTINGS" MENU.ITEM( SCS.385 )
    3 2 " READ SAVED SETTINGS" MENU.ITEM( RSS.385 )
MENU.END
```

Appendix K - Program: LBA.XXX (Spiricon - Laser Beam Analyzer)

```
\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\ \
\                                                                       \
\                    Spiricon - LBA100 Laser Beam Analyzer              \
\                                                                       \
\    *** This program has been fully completed. Some details need to be \
\        worked out with the data display, except for the beam profile. \
\                                                                       \
\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\ \
\
\ ************************** DECLARE VARIABLES *************************** /
\
\ DECLARE VARIBLES & LOAD WITH DEFAULT DATA

 DIM[ 40 , 20 ] STRING.ARRAY  D.LBA     \ DATA DESCRIPTIONS
   14440 STRING LBAS                    \ GPIB STRING FOR PICTURE
      15 STRING LBACOM                  \ LBA FRAME COMMENT
       2 STRING FRAME                   \ FRAME #
 INTEGER SCALAR LBAO   0 LBAO :=        \ CHECK IF LBA WAS JUST INITIALIZED
 INTEGER DIM[ 800 ] ARRAY DLBA.TEXT     \ LBA TEXT DATA, USED FOR STRING TO
                                        \   INTEGER CONVERSION.

 TOKEN DATAR    \  DATA ARRAYS
 TOKEN DATAS    \
 TOKEN DATA1    \
 TOKEN DATA2    \
 TOKEN DATA3    \
 TOKEN DAT      \

: RELOAD.LBA
 ?EXP.MEM IF                     \ CHECK IF AN EMM IS PRESENT IN DOS.
        EXP.MEM> DATAR           \ IF EMM IS PRESENT, TOKENS ARE PLACED
        EXP.MEM> DATAS           \    INTO EXPANDED MEMORY.
        EXP.MEM> DATA1           \
        EXP.MEM> DATA2           \
        EXP.MEM> DATA3           \
        EXP.MEM> DAT             \
 THEN                            \ OTHERWISE THEY BECOME ARRAYS
  INTEGER DIM[  220 ]   UNNAMED.ARRAY BECOMES> DATAR
  INTEGER DIM[ 220 ]    UNNAMED.ARRAY BECOMES> DATAS
  INTEGER DIM[ 7220 ]   UNNAMED.ARRAY BECOMES> DATA1
  INTEGER DIM[ 120 , 120 ] UNNAMED.ARRAY BECOMES> DATA2
  INTEGER DIM[ 120 , 120 ] UNNAMED.ARRAY BECOMES> DATA3
  INTEGER DIM[ 60 ] UNNAMED.ARRAY BECOMES> DAT
;
RELOAD.LBA
```

```
      MENU LBA.MENU             \ DECLARE MENUS
      MENU SRLBA                \
      VUPORT LBA.PORT           \ DECLARE VUPORT IN GRAPHICS DISPLAY

       0 .252 VUPORT.ORIG       \    ORIGIN
       1 .748 VUPORT.SIZE       \    SIZE
 20 0 25 80 WINDOW LBA.WIN      \ DECLARE GRAPHICS WINDOW

\ ************************* COLON DEFINITIONS ************************* /


: LBAONE        \ IF IT IS FIRST COMMUNICATION, YOU HAVE TO SEND " :REM"
    0 LBAO = IF  LBA_100 " :REM" GW  COM GR
    THEN 2 LBAO := ;

: RLBAF         \ READ A FRAME OF DATA FROM THE LBA
    " :CAP 1 " "CR.LF" "CAT GW
    " :KRS " "CR.LF" "CAT GW
    " :STS? " "CR.LF" "CAT GW
    LBAS GR
    LBAS 44 "NUMBER SS.CLEAR "." FRAME ":=
    40 20 GOTO.XY ." .... READING FRAME #  " FRAME "TYPE
    " :RDD? " FRAME "CAT "CR.LF" "CAT COM ":= COM GW
    LBAS GR LBAS 14 14393 "SUB DATA1 ">ARRAY
    " :FST? " FRAME "CAT "CR.LF" "CAT COM ":= COM GW
    LBAS GR LBAS 5 240 "SUB DATAS ">ARRAY
    " :RDR? " FRAME "CAT "CR.LF" "CAT COM ":= COM GW
    LBAS GR LBAS 7 200 "SUB DATAR ">ARRAY
 ;


: GLBAF         \ GRAPH LBA PICTURE
     16 GRAPHICS.DISPLAY.MODE        \ GRAPHICS MODE
     GRAPHICS.DISPLAY                \ GO TO GRAPHICS DISPLAY
     LBA.WIN                         \ USE GRAPHICS WINDOW
     LBA.PORT                        \ USE GRAPHICS VUPORT
     VUPORT.CLEAR                    \ CLEAR VUPORT
     OUTLINE                         \ OUTLINE THE VUPORT
     {BORDER}                        \ OUTLINE THE WINDOW

     121 1 DO                        \ REPLOT PICTURE PIXEL BY PIXEL
      121 1 DO
          DATA2 [ J , I ] COLOR
        I 2 * 396 + M := M 1 + Y :=
        J 2 * L :=
        348 L - N := N 1 - Z :=
          M N P!  M Z P!
          Y N P!  Y Z P!
      LOOP
```

```
LOOP

3 COLOR                         \ LABEL DATA

.05 .96 POSITION " Total            "    LABEL
.05 .92 POSITION " Peak             "    LABEL
.05 .88 POSITION " Peak Loc         "    LABEL
.05 .84 POSITION " Centroid         "    LABEL
.05 .80 POSITION " Diameter         "    LABEL
.05 .72 POSITION " Elliptical Beam  "    LABEL
.05 .68 POSITION " Major Axis       "    LABEL
.05 .64 POSITION " Minor Axis       "    LABEL
.05 .60 POSITION " Orientation      "    LABEL
.05 .56 POSITION " Roundness        "    LABEL
.05 .50 POSITION " Gauss fit        "    LABEL
.05 .44 POSITION " CTR, Width       "    LABEL
.05 .41 POSITION " Height           "    LABEL
.05 .38 POSITION " Correlation      "    LABEL
.05 .33 POSITION " ctr, width       "    LABEL
.05 .30 POSITION " height           "    LABEL
.05 .27 POSITION " correlation      "    LABEL
.35 .96 POSITION " Top Hat          "    LABEL
.35 .92 POSITION " Mean             "    LABEL
.35 .88 POSITION " Dev              "    LABEL
.35 .84 POSITION " Min              "    LABEL
.35 .80 POSITION " Max              "    LABEL
.35 .72 POSITION "                  "    LABEL
.35 .68 POSITION " Divergeance      "    LABEL
.35 .64 POSITION " * -              "    LABEL
.35 .60 POSITION " Elliptical       "    LABEL
.35 .56 POSITION " ELLIPSE          "    LABEL
.35 .50 POSITION " SPIRICON         "    LABEL
.35 .44 POSITION " by BKD           "    LABEL
.35 .41 POSITION "                  "    LABEL
.35 .38 POSITION "                  "    LABEL
.35 .33 POSITION "                  "    LABEL

CURSOR.OFF

LBA.WIN
2 2 GOTO.XY ." ENTER PCX FILENAME: "
"INPUT FILE.NAME ":-
500 MSEC.DELAY
2 2 GOTO.XY ." ..... NOW SAVING PCX IMAGE TO FILE  "
FILE.NAME DEFER> VUP>PCX
"INPUT SS.CLEAR
MENU.ESCAPE
;
```

```
: G.LBA.F      \ GRAPHING A FRAME FROM THE LBA
    40 20 GOTO.XY ." ..... UNPACKING COMPRESSED DATA"

     121 1 DO   \ CONVERT PACKED INTEGER DATA TO PIXEL INTEGER DATA FORMAT
          I 60 * 59 - X :=
          DATA1 SUB[ X , 60 ] DAT :=
          DAT UNPACK DATA2 XSECT[ I , ! ] :=
          DATA2 XSECT[ I , ! ] 16 / DATA3 XSECT[ I , ! ] :=
     LOOP
     GLBAF      \ GRAPH THE PICTURE
     "INPUT SS.CLEAR ;

: SLBA                              \ SAVE PICTURE DATA
    " FRAME# " FRAME "CAT LBACOM ":=     \
    SAVE.RESTORE.MENU MENU.EXECUTE       \
    LARGE.DATAFILE                       \
    FILE.TEMPLATE                        \
     1 COMMENTS                          \
     INTEGER DIM[ 120 , 120 ] SUBFILE    \
    END                                  \
    FILE.NAME DEFER> FILE.CREATE         \
    FILE.NAME DEFER> FILE.OPEN           \
    1 SUBFILE DATA2 ARRAY>FILE           \
    LBACOM 1 >COMMENT                    \
    FILE.CLOSE MENU.ESCAPE MENU.ESCAPE    ;


: RLBA                              \ RESTORE PICTURE DATA
    SAVE.RESTORE.MENU MENU.EXECUTE       \
    FILE.NAME DEFER> FILE.OPEN           \
    1 SUBFILE DATA2 FILE>ARRAY           \
    1 COMMENT> LBACOM ":=                \
    FILE.CLOSE                           \
    MENU.ESCAPE MENU.ESCAPE  ;           \


SRLBA
    2 50 6 76 MENU.SHAPE
    3 0 MENU.COLOR
    14 MENU.PROMPT.COLOR
    1 2 " GO TO THE O.K. PROMPT" MENU.ITEM( OKP )
    2 2 " SAVE CURRENT SETTINGS" MENU.ITEM( SLBA )
    3 2 " READ SAVED SETTINGS" MENU.ITEM( RLBA )
MENU.END
```

```
\ ************************* SPRICON MENU ******************************* /

: LBA.STAT
    LBA_100
    LBAONE
    11 FOREGROUND ;


LBA.MENU
   " LASER BEAM ANALYZER" MENU.TITLE
   MENU.STATUS LBA.STAT
   MENU.BLOW.UP
   1 1 24 78 MENU.SHAPE
   0 11 MENU.COLOR
   15 MENU.PROMPT.COLOR
   MENU.STORE.DISK
   3 5 " READ A FRAME " MENU.ITEM{ RLPAF }
   5 5 " GRAPH A FRAME"  MENU.ITEM{ G.LBA.F }
   8 5 " SAVE & RESTORE" MENU.ITEM{ SRLBA }
MENU.END
```

Appendix L - Program: JOE.XXX (Non-Linear Optical Switch Test)

```
\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
\                                                                  \
\         Non-Linear Optical Switch Test Control Program  (NLOSTCP)        \
\                                                                  \
\ \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
\
\ ************************** DECLARE VARIABLES *************************** /
\
\ DECLARE VARIBLES & LOAD WITH DEFAULT DATA
\
     5 STRING INT                                  \ Number of Intervals
    20 STRING D.W                                  \ Read W axis Display
     8 STRING KMD.S                                \ Klinger Motor String
    30 STRING FNAME   " D:\NLINTSW" FNAME ":=      \ Default File Name

   INTEGER SCALAR CDETEC      2 CDETEC :=     \ Change Detector
   INTEGER SCALAR KMD.N                       \
   INTEGER SCALAR OPTIONJ                     \ Joe's Options
DP.INTEGER SCALAR V                           \
DP.INTEGER SCALAR U                           \
      REAL SCALAR STRING.NUM                  \ Convert String to Number
   DP.REAL SCALAR DEGREE                      \ Substrate Angle of Reflection
DP.REAL DIM[ 1000 , 2 ] ARRAY DATA123 0 DATA123  =
" NO" INT.PAUSE ":=

TOKEN TOTAL      TOKEN XCOOR
TOKEN DEGREES    TOKEN YCOOR
TOKEN PEAK       TOKEN ZCOOR
TOKEN DATA.123

: RELOAD.JOE
     ?EXP.MEM IF
          EXP.MEM> TOTAL         EXP.MEM> XCOOR
          EXP.MEM> DEGREES       EXP.MEM> YCOOR
          EXP.MEM> PEAK          EXP.MEM> ZCOOR
          EXP.MEM> DATA.123
     THEN
 1000 DP.REAL  RAMP BECOMES> TOTAL
 1000 DP.REAL  RAMP BECOMES> DEGREES
 1000 DP.REAL  RAMP BECOMES> PEAK
 0 TOTAL := 0 DEGREES := 0 PEAK :=
;
RELOAD.JOE
```

```
\ ************************** DECLARE MENUS ****************************** /

                        MENU SAVE.RESTORE.JOE.MENU
                        MENU LBA.TOTAL.FILE.MENU
                        MENU DATA.TO.123
                        MENU OPTIONJ.MENU
                        MENU CDETECTOR.MENU
                        MENU JOE.MENU

\ ************************ COLON DEFINITIONS *************************** /

: CNS          \ CHANGE NUMBER OF STEPS PER INTERVAL
 20 14 GOTO.XY ." ENTER THE NUMBER OF DEGREES BETWEEN INTERVALS"
 40 16 GOTO.XY  7 BACKGROUND CLRSCR 1 4 "SUB "TYPE
 40 16 GOTO.XY  "INPUT SPI ":= 0 BACKGROUND
 40 16 GOTO.XY CLRSCR 1 5 "SUB "TYPE
 SPI 0 "NUMBER KMD.N := SS.CLEAR KMD.N 0 >
 IF " +" PN ":= ELSE " -" PN ":= THEN
 KMD.N ABS "." SPI ":=      ;

: CPI          \ CHANGE POWER PER INTERVAL
 20 14 GOTO.XY ." ENTER THE DESIRED CHANGE IN POWER PER INTERVAL"
 40 16 GOTO.XY  7 BACKGROUND CLRSCR 1 4 "SUB "TYPE
 40 16 GOTO.XY  "INPUT SPI ":= 0 BACKGROUND
 40 16 GOTO.XY CLRSCR 1 5 "SUB "TYPE     ;


: CNI          \ INPUT NUMBER OF INTERVALS
 20 14 GOTO.XY ." ENTER THE NUMBER OF INTERVALS ( 1 - 1000 )    "
 40 16 GOTO.XY  7 BACKGROUND CLRSCR 1 4 "SUB "TYPE
 40 16 GOTO.XY  "INPUT INT  ":=   0 BACKGROUND
 40 16 GOTO.XY CLRSCR 1 5 "SUB "TYPE
 20 14 GOTO.XY CLRSCR "TYPE 60 15 GOTO.XY CLRSCR 1 15 "SUB "TYPE
 INT 0 "NUMBER Q :=                    ;

: NO.DEGREES   \ DISPLAY THE NUMBER OF DEGREES OF THE SUBSTRATE
   MC4A
   " DW" GW
   D.W GR D.W 3 20 "SUB 0 "NUMBER 1000.0 / RX :=
   SS.CLEAR STACK.CLEAR
   MC4B
   " DZ" GW
   D.W GR D.W 3 20 "SUB 0 "NUMBER 100.0 / RY :=
   RX RY + DEGREE :=
   SS.CLEAR   STACK.CLEAR
   30 5 GOTO.XY ." DEGREES: " DEGREE .  ;
```

```
: IID    1 OPTIONJ :- MENU.ESCAPE ; \ OPTION - CHANGE REFLECTION ANGLE
: ILP    2 OPTIONJ :- MENU.ESCAPE ; \ OPTION - CHANGE LASER POWER
: IIDAZ  3 OPTIONJ :- MENU.ESCAPE ; \ OPTION - CHANGE ANGLE THEN HEIGHT

OPTIONJ.MENU                        \ OPTIONS MENU
    2 50 4 76 MENU.SHAPE
    MENU.NO.BORDER
    3 0 MENU.COLOR
    14 MENU.PROMPT.COLOR
    0 2 " INCREMENT IN DEGREES" MENU.ITEM( IID )
    1 2 " INCREMENT LASER POWER" MENU.ITEM( ILP )
    2 2 " DEGREES &  Z AXIS" MENU.ITEM( IIDAZ )
MENU.END

: JO       \ ************** MAIN PROGRAM ************************** /

    OPTIONJ.MENU   MENU.EXECUTE     \ FIRST, ASK FOR OPTIONS
    1 X :-  12 FOREGROUND           \
    1 CDETEC - IF     1 BACKGROUND  \ IF YOU ARE USING THE LBA, EACH PICTURE
                                    \  MUST BE STORED IMMEDIATELY DUE TO
                                    \ MEMORY CONSTRAINTS.
           25 16 GOTO.XY ."  LEAVE OFF FILE EXTENSION "
           20 17 GOTO.XY ."  FILENAME MUST BE LESS THAN 6 LETTERS "
           SAVE.RESTORE.MENU MENU.EXECUTE FILE.PATH " \V" "CAT NAME.FILE "CAT
           FNAME ":- 0 BACKGROUND
           25 16 GOTO.XY CLRSCR "TYPE
           20 17 GOTO.XY CLRSCR "TYPE 50 17 GOTO.XY CLRSCR   10 "SUB "TYPE
    THEN
    OPTIONJ CASE                    \ ASK FOR PARAMETERS FOR CHOSEN
       1 OF CNS CNI  ENDOF          \ TEST OPTION.
       2 OF CPI CNI  ENDOF          \
       3 OF CNS CNI                 \
           40 13 GOTO.XY ." ENTER NUMBER OF Z AXIS MOVES"
           7 BACKGROUND 50 14 GOTO.XY CLRSCR 1 5 "SUB "TYPE
           50 14 GOTO.XY "INPUT SS ":- SS 0 "NUMBER X :- SS.CLEAR
           X 1 < IF 1 X :- THEN 0 BACKGROUND
           40 13 GOTO.XY ." ENTER Z AXIS STEPS PER MOVE "
           7 BACKGROUND 50 14 GOTO.XY CLRSCR 1 5 "SUB "TYPE
           50 14 GOTO.XY "INPUT SS ":-
           " NZ" SS "CAT COM ":- COM GW
           20 FOREGROUND 2 BACKGROUND
           1 CDETEC <> IF             \ LBA MUST SAVE AFTER EACH MOVE
           20 6 GOTO.XY ."  LEAVE OFF FILE EXTENSION "  0 BACKGROUND
           2 SAVE.RESTORE.MENU MENU.EXECUTE  FILE.PATH " \" "CAT NAME.FILE "CAT
           FNAME ":-  MENU.ESCAPE THEN ENDOF
    ENDCASE

    11 FOREGROUND
    SPI 0 "NUMBER KMD.N :- SS.CLEAR
```

```
  2 OPTIONJ <> IF                 \ SET THE DIRECTION AND NUMBER
      MC4A                        \   OF STEPS FOR THE KLINGER MOTORS
      PN " +" IF " -W" COM ":= ELSE " +W" COM ":= THEN COM GW
      KMD.N 1000.0 * Z := Z "." SS ":=
      " NW" SS "CAT COM ":= COM GW
      MC4B
      PN " Z" "CAT SS ":= SS GW
      KMD.N 200.0 * Z := Z "." SS ":=
      " NZ " SS "CAT SS ":= SS GW
      Q 1 + Q := 12 FOREGROUND
  THEN

X 1 DO           \ ***** START PROGRAM LOOPS ******** /
  Q 1 DO
        INT.PAUSE " YES" "=
      IF     20 28 GOTO.XY PAK "TYPE PCKEY
      ELSE   2000 MSEC.DELAY     THEN

      1 CDETEC = IF
             LBA_100          \ USING SPIRICON LASER BEAM ANALYZER
             LBAONE           \ BECAUSE OF THE SIZE IT MUST BE SAVED
             RLBAF            \ IMMEDIATELY FOLLOWING BEING RECEIVED
             LBAS 12 20 "SUB 44 "NUMBER TOTAL [ I ] :=
             ?DROP 44 "NUMBER PEAK [ I ] :=

              FNAME J "." 2 "LEN 2 - "SUB "CAT  FILE.NAME ":=
              FILE.NAME " ." "CAT I "." 2 "LEN 2 - "SUB "CAT FILE.NAME ":=
              LARGE.DATAFILE
              FILE.TEMPLATE
                INTEGER DIM[ 7220 ] SUBFILE
                INTEGER DIM[ 220 ] SUBFILE
                INTEGER DIM[ 220 ] SUBFILE
              END
              FILE.NAME DEFER> FILE.CREATE
              FILE.NAME DEFER> FILE.OPEN
                1 SUBFILE DATA1 ARRAY>FILE
                2 SUBFILE DATAR ARRAY>FILE
                3 SUBFILE DATAS ARRAY>FILE
              FILE.CLOSE
              5 21 GOTO.XY ." .... SAVING TO " FILE.NAME "TYPE
      ELSE
             NWPM835           \ USING POWER METER FOR BEAM DETECTION
             RESULTS.100 GR
             RESULTS.100 4 20 "SUB 44 "NUMBER TOTAL [ I ] :=
      THEN

      SS.CLEAR       14 FOREGROUND
      NO.DEGREES              \ REDISPLAY THE SUBSTRATE ANGLE
      DEGREE DEGREES [ I ] :=
```

```
    30 15 GOTO.XY ." TOTAL POWER: " TOTAL [ I ] 1000 * . ."  mW   "

   OPTIONJ 2 = IF                   \ LPC POWER IS RAMPED
        LPC                         \
        " P ? " "CR.LF" "CAT GW     \
        COM GR COM 32 "NUMBER STRING.NUM := SS.CLEAR
        STRING.NUM KMD.N + STRING.NUM :=
        STRING.NUM "." COM ":=
        " W"  UNITS ":=
        " P " COM "CAT UNITS "CAT COM ":= COM GW
   ELSE                             \ OTHERWISE THE KLINGER MOTORS MOVE
        MC4B " MZ" GW               \
        MC4A " MW" GW " BW" SS "CAT COM ":= COM GW
   THEN
    SS.CLEAR      65 9 GOTO.XY ." INCREMENT #"
    12 FOREGROUND 65 10 GOTO.XY I . ."  OF " Q .
 LOOP

   3 OPTIONJ = IF            \ AUTOMATICALLY SAVE DATA AFTER EACH
       J "." SS ":=          \  CHANGE IN THE Z AXIS
       FNAME " ." "CAT SS "CAT FILE.NAME ":=
       LARGE.DATAFILE
       FILE.TEMPLATE
         1 COMMENTS
         DP.REAL DIM[ 1000 ] SUBFILE
         DP.REAL DIM[ 1000 ] SUBFILE
         DP.REAL DIM[ 1 ] SUBFILE
         1 CDETEC = IF DP.REAL DIM[ 1000 ] SUBFILE THEN
       END
       FILE.NAME DEFER> FILE.CREATE
       FILE.NAME DEFER> FILE.OPEN
         1 SUBFILE TOTAL ARRAY>FILE
         2 SUBFILE DEGREES ARRAY>FILE
         3 SUBFILE C.FACTOR ARRAY>FILE
         C.FACTOR.UNIT 1 >COMMENT
       FILE.CLOSE
       MC4A  " MZ" GW
  THEN
  Q 1 - Q :=
LOOP
2000 440 TUNE
1000 220 TUNE
2000 880 TUNE
11 FOREGROUND ;

\ ******************* END OF LOOP PROGRAM: JOE ************************* /

: MOVE.SETUP        \ THIS ROUTINE CALCULATES THE CURRENT SUBSTRATE ANGLE
  MC4A " DW" GW     \  FROM THE COUNTERS OF THE TWO ROTATIONAL STAGES,
```

```
D.W GR D.W 3 20 "SUB 0 "NUMBER V :=  SS.CLEAR   \ THEN CALCULATES THE
MC4B " DZ" GW                                   \ NEEDED POSITIONS FOR A
D.W GR D.W 3 20 "SUB 0 "NUMBER X :=  SS.CLEAR   \ DESIRED ANGLE.
X 5 * V + 1000 / RX :=                          \  RX = CURRENT ANGLE
                  \ MC4B "Z" IS THE DETECTOR AND MUST BE POSITIONED AT
                  \ AN ANGLE TWICE THE SIZE OF MC4A "W" ( THE SUBSTRATE).
                  \ THE MC4B "Z" AXIS STAGE IS 100 COUNTS PER DEGREE
                  \ THE MC4A "W" AXIS STAGE IS 1000 COUNTS PER DEGREE
                  \ THEREFORE THE COUNT DIFFERENCE IS 1/5.
13 FOREGROUND
25 21 GOTO.XY ." INPUT THE NUMBER OF DEGREES FOR THE SETUP"
11 FOREGROUND 7 BACKGROUND
50 5 GOTO.XY CLRSCR 1 10 "SUB "TYPE
50 5 GOTO.XY "INPUT SS ":= SS 0 "NUMBER KMD.N := SS.CLEAR
MC4A            \ CALCULATE FROM PREVIOUS POSITION THE NEW POSITION
RX 2 * KMD.N - 1000 * V := V "." SS ":= " PW" SS "CAT SS ":= SS GW
MC4B KMD.N RX < IF RX KMD.N := THEN
KMD.N RX - 200 * U := U "." SS ":= " PZ" SS "CAT SS ":= SS GW
STACK.CLEAR SS.CLEAR
13 FOREGROUND  0 BACKGROUND
25 21 GOTO.XY ." WAIT FOR THIS MESSAGE TO DISSAPEAR        "
11 FOREGROUND ;


: GTOTAL              \ GRAPH THE DATA PREVIOUSLY TAKEN
   GRAPHICS.DISPLAY
   DEGREES SUB[ 1 , Q ] BECOMES> XCOOR
   TOTAL SUB[ 1 , Q ] BECOMES> YCOOR
   PEAK SUB[ 1 , Q ] BECOMES> ZCOOR
   XCOOR YCOOR
   XY.AUTO.PLOT
   1 CDETEC = IF ZCOOR Y.DATA.PLOT THEN
   "INPUT  SS.CLEAR
;

: STOP.AE.INT         \ CHOOSE WHETHER TO STOP BETWEEN TAKING DATA
   INT.PAUSE " YES" "= IF " NO " INT.PAUSE ":=
   ELSE " YES" INT.PAUSE ":= THEN ;
```

```
\ *********** SAVE & RESTORE IN ASYST FORMAT

: SLBA.TOTAL                              \ SAVE CURRENT SETTINGS
    SAVE.RESTORE.MENU MENU.EXECUTE        \         IN
    FILE.PATH " \" "CAT                   \
    NAME.FILE "CAT FILE.NAME ":=          \
    LARGE.DATAFILE                        \   ASYST FORMAT
    FILE.TEMPLATE                         \
     1 COMMENTS                           \
     DP.REAL DIM[ 1000 ] SUBFILE          \
     DP.REAL DIM[ 1000 ] SUBFILE          \
     DP.REAL DIM[ 1 ] SUBFILE             \
    1 CDETEC = IF                         \
     DP.REAL DIM[ 1000 ] SUBFILE THEN     \
    END                                   \
    FILE.NAME DEFER> FILE.CREATE          \
    FILE.NAME DEFER> FILE.OPEN            \
    1 SUBFILE TOTAL ARRAY>FILE            \
    2 SUBFILE DEGREES ARRAY>FILE          \
    3 SUBFILE C.FACTOR ARRAY>FILE         \
    1 CDETEC = IF                         \
         4 SUBFILE PEAK ARRAY>FILE THEN   \
    C.FACTOR.UNIT 1 >COMMENT              \
    FILE.CLOSE MENU.ESCAPE MENU.ESCAPE     ;

: RLBA.TOTAL                              \ RESTORE SAVED SETTINGS
    SAVE.RESTORE.MENU MENU.EXECUTE        \
    FILE.PATH " \" "CAT                   \     IN ASYST FORMAT
    NAME.FILE "CAT FILE.NAME ":=          \
    FILE.NAME DEFER> FILE.OPEN            \
    1 SUBFILE TOTAL FILE>ARRAY            \
    2 SUBFILE DEGREES FILE>ARRAY          \
    3 SUBFILE C.FACTOR FILE>ARRAY         \
    1 CDETEC = IF                         \
         4 SUBFILE PEAK FILE>ARRAY THEN   \
    1 COMMENT> C.FACTOR.UNIT ":=          \
    FILE.CLOSE                            \
    MENU.ESCAPE MENU.ESCAPE  ;

LBA.TOTAL.FILE.MENU
    2 50 6 76 MENU.SHAPE
    3 0 MENU.COLOR
    14 MENU.PROMPT.COLOR
    1 2 " GO TO THE O.K. PROMPT" MENU.ITEM( OKP )
    2 2 " SAVE CURRENT SETTINGS" MENU.ITEM( SLBA.TOTAL )
    3 2 " READ SAVED SETTINGS" MENU.ITEM( RLBA.TOTAL )
MENU.END
```

```
\ *********** SAVE & RESTORE IN LOTUS 1-2-3 FORMAT

: S123
    TOTAL      DATA123 XSECT[ ! , 1 ] :=
    DEGREES    DATA123 XSECT[ ! , 2 ] :=
    DATA123 SUB[ 1 , Q ; 1 , 2 ] EQUIV> DATA.123
    SAVE.RESTORE.MENU MENU.EXECUTE        \
    FILE.PATH " \" "CAT                   \
    NAME.FILE "CAT FILE.NAME ":=          \
    FILE.NAME DEFER> 123FILE.CREATE       \
    FILE.NAME DEFER> 123FILE.OPEN         \
    1 1 123WRITE.ACROSS                   \
    1 1 Q 2 123READ.RANGE                 \
    DATA.123 ARRAY>123FILE                \
    123FILE.CLOSE  MENU.ESCAPE MENU.ESCAPE \
;


: R123                              \ RESTORE SAVED SETTINGS
    SAVE.RESTORE.MENU MENU.EXECUTE \
    FILE.PATH " \" "CAT            \     IN LOTUS 1-2-3
    NAME.FILE "CAT FILE.NAME ":=   \
    FILE.NAME DEFER> 123FILE.OPEN  \
    WKS.INFO [ 4 , 1 ] Q :=        \
    DATA123 SUB[ 1 , Q ; 1 , 2 ] EQUIV> DATA.123
    1 1 Q 2 123READ.RANGE
    DATA.123 123FILE>ARRAY
    123FILE.CLOSE
    Q 1 + Z :=
    Z 1 DO
    DATA123 [ I , 1 ] TOTAL [ I ] :=
    DATA123 [ I , 2 ] DEGREES [ I ] :=
    LOOP    MENU.ESCAPE MENU.ESCAPE
;
```

```
: C123                    \ CONVERT DATA SAVED IN ASYST FORMAT TO LOTUS FORMAT
    CLRSCR  FILE.NAME ":=     \ AND PLACE ON DISK IN DRIVE A:
    SAVE.RESTORE.MENU MENU.EXECUTE
    FILE.PATH " \" "CAT
    NAME.FILE "CAT FILE.NAME ":=
    FILE.NAME  SS ":= FILE.NAME " .DAT" "CAT FILE.NAME ":=
    FILE.NAME DEFER> FILE.OPEN
    1 SUBFILE TOTAL FILE>ARRAY
    2 SUBFILE DEGREES FILE>ARRAY
    3 SUBFILE C.FACTOR FILE>ARRAY
    1 COMMENT> C.FACTOR.UNIT ":=
    FILE.CLOSE    SS FILE.NAME ":=
    " A:\" FILE.NAME "CAT " .WK1" "CAT FILE.NAME ":=
    Q 1 + Q := Q 1 DO
    TOTAL [ I ]   DATA123 [ I , 1 ] :=
    DEGREES [ I ]   DATA123 [ I , 2 ] :=
    LOOP  Q 1 - Q :=
    DATA123 SUB[ 1 , Q ; 1 , 2 ] BECOMES> DATA.123
    FILE.NAME DEFER> 123FILE.CREATE
    FILE.NAME DEFER> 123FILE.OPEN
    1 1 123WRITE.ACROSS
    DATA.123 ARRAY>123FILE
    123FILE.CLOSE  SS FILE.NAME ":= MENU.ESCAPE MENU.ESCAPE ;

DATA.TO.123
    2 50 7 76 MENU.SHAPE
    3 0 MENU.COLOR
    14 MENU.PROMPT.COLOR
    1 2 " GO TO THE O.K. PROMPT" MENU.ITEM{ OKP }
    2 2 " SAVE CURRENT SETTINGS" MENU.ITEM{ S123 }
    3 2 " READ SAVED SETTINGS" MENU.ITEM{ R123 }
    4 2 " CONVERT FROM C: TO A:" MENU.ITEM{ C123 }
MENU.END


SAVE.RESTORE.JOE.MENU
   MENU.NO.BORDER
   MENU.BLOW.UP
   19 50 21 68 MENU.SHAPE
   3 0 MENU.COLOR
   14 MENU.PROMPT.COLOR
   MENU.STORE.DISK
   1 5 " LOTUS 1-2-3" MENU.ITEM{ DATA.TO.123 }
   1 21 " ASYST FORMAT" MENU.ITEM{ LBA.TOTAL.FILE.MENU }
MENU.END


: CDETEC1   1 CDETEC :=  MENU.ESCAPE ;
: CDETEC2   2 CDETEC :=  MENU.ESCAPE ;
```

```
\ ************************** NLOSTCP MENUS ******************************* /

CDETECTOR.MENU           \ MENU TO CHANGE DETECTOR TYPES
   MENU.NO.BORDER
   MENU.BLOW.UP
   9 30 10 76 MENU.SHAPE
   0 11 MENU.COLOR
   13 MENU.PROMPT.COLOR
   MENU.STORE.DISK
   1 10 " BEAM ANALYZER" MENU.ITEM( CDETEC1 )
   1 30 " POWER METER" MENU.ITEM( CDETEC2 )
MENU.END

: JOE.STATUS
    0 background
    14 FOREGROUND
    50 11 GOTO.XY INT.PAUSE "TYPE
    NO.DEGREES  0 background
         1 CDETEC = IF 40 9 GOTO.XY ." SPIRICON LBA"
    ELSE 2 CDETEC = IF 40 9 GOTO.XY ." POWER METER "
                  ELSE 40 9 GOTO.XY ." NO DETECTOR" THEN
    THEN
    13 FOREGROUND
    5 1 GOTO.XY ."    Don't try this at home!!"
    5 2 GOTO.XY ." made for Joe Osman & Joe Chaiken"
    11 FOREGROUND
;

JOE.MENU
   " OPTICAL SWITCH TEST PROGRAM" MENU.TITLE
   MENU.BLOW.UP
   MENU.STATUS JOE.STATUS
   1 1 24 78 MENU.SHAPE
   0 11 MENU.COLOR
   15 MENU.PROMPT.COLOR
   MENU.STORE.DISK
   5 5 " MOVE SETUP " MENU.ITEM( MOVE.SETUP )
   7 5 " CHANGE POWER LEVEL" MENU.ITEM( CLPCP )
   9 5 " CHANGE DETECTOR" MENU.ITEM( CDETECTOR.MENU )
  11 5 " STOP AT EACH INTERVAL ? " MENU.ITEM( STOP.AE.INT )
  14 5 " RUN PROGRAM" MENU.ITEM( JO )
  17 5 " GRAPH DATA" MENU.ITEM( GTOTAL )
  19 5 " RESTORE & SAVE DATA " MENU.ITEM( SAVE.RESTORE.JOE.MENU )
MENU.END
```

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Laser Chemistry of Organometallics as a General Synthetic Route to Metal Clusters

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We show that gas-phase organometallics can be photolyzed using pulsed UV–visible lasers to initiate synthesis of metal clusters. We use the log-normal distribution function to compare this new method of cluster formation to other methods. Cluster size distributions produced using this new method bear a remarkable similarity to those produced using nozzle beam expansion methods. Although there is deviation from this distribution, these growth methods would seem to involve coalescence growth mechanisms as opposed to Ostwald ripening. Possible reasons for the deviation from a log-natural distribution are suggested. Laser chemistry allows synthesis of gas-phase metal clusters because of the very high pressures of metal atoms attainable using multiphoton dissociation of organometallics.

Introduction

Clusters[1] of atoms and molecules span the transition from quantum mechanical to classical objects and have been synthesized[2,3] using sintering and heated wire evaporation, laser vaporization combined with a supersonic expansion,[4] and related methods[5] which utilize ovens. We show that gas-phase organometallics can be photolyzed using pulsed UV–visible lasers to initiate synthesis of metal clusters. We use the log-normal distribution function[2,3,6] to compare this new method of cluster formation to the other methods. Cluster size distributions produced using this new method bear a remarkable similarity to those produced using the nozzle beam expansion methods. Although there is some deviation from this distribution, both methods would seem to involve coalescence growth[7] as opposed to Ostwald ripening.[7] Laser chemistry allows synthesis of gas-phase metal clusters because of the very high pressures of metal atoms attainable using multiphoton dissociation of organometallics.

Multiphoton dissociation of organometallics is widely known[8-12] to produce free metal atoms, ions, and other fragmentation products which coalesce to produce LCVD films.[13,14] Because

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(11) Samorjski, B.; Chaiken, J. *J. Chem. Phys.* **1989**, *90*, 4079–4090.
(12) Samorjski, B.; Chaiken, J. *Phys. Rev. A* **1988**, *38*, 3498–3503.

0022-3654/92/2096-3183$03.00/0

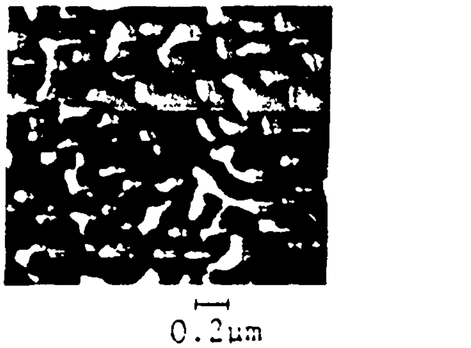

Figure 1. Scanning electron micrograph of transparent platinum films on quartz substrate. Auger electron spectroscopy shows that the bright regions are nearly pure platinum and dark regions are voids which extend to the subtrate.

these films are composed of clusters, it is reasonable to suspect that they could have unusual optical and electrical properties.[15,16] Puretsky and Dem'yanenko[17] reported over a year ago that nanosecond excimer laser pulses could be used to produce clouds of metal clusters and ultrafine particles from gas-phase metal carbonyls. Their estimate on the size and shape distribution was based on mobility measurements in which the number densities and temperatures of the populations produced could not be known independently. Nevertheless, their evidence for the existence of clusters and ultrafine particles was convincing. Similar experiments were reported much earlier by Tam and co-workers[18] and others.[19] The Smalley laser vaporization/supersonic expansion technique, and oven based versions, produce collision-free gas-phase samples having cluster densities of $\approx 10^{10}$ cm^{-3}. The new technique promises to allow production of gas-phase number densities exceeding $\approx 10^{15}$ clusters/cm^{3} using even the most refractory metals.

Experimental Section

Although our basic method for LCVD has been described earlier, an extensive description of our new apparatus is in preparation. Films are deposited by directing a series of masked, unfocused, ≈10-mJ, 20-ns, 308-nm laser pulses (Lambda Physik EMG 101) into a chamber containing an organometallic vapor and possibly other gases. The laser entrance window and exit window are the substrates, or other objects can be placed in the cell to serve as substrates. The laser may or may not contact the substrate and the gas phase may be flowing or stagnant. Although the rate of film growth is maximized where the substrates are irradiated, there is deposition of particulate material which, depending on conditions, can be detected in stagnant deposition cells over long periods of time.

The organometallic precursors employed in the current study were allylcyclopentadienylplatinum[20] and trimethyl(methylcyclopentadienyl)platinum.[21] Each precursor has a room-temperature vapor pressure of >30 and ≈44 mTorr, respectively. The films used in this study were deposited over 40 min using 12 000 laser pulses, with the grid in contact with the laser beam and with a stagnant ≈ 2 Torr total pressure. TEM and electron diffraction data was obtained using a JEOL (JEM 7A) instrument and the SEM was obtained using a Perkin-Elmer PHI 600 Scanning Auger Multiprobe.

(13) For an overview of LCVD, see for example: Bauerle, D. *Chemical Processing with Lasers*; Springer: Berlin, 1986; Springer Series in Materials Science, Vol. 1. For a diagram of our simple LCVD apparatus see: Rooney, D.; Negrotti, D.; Byassee, T.; Macero, D.; Vastag, B.; Chaiken, J. *J. Electrochem. Soc.* **1990**, *137*, 1162–1166. See also: Chaiken, J. US Patent 4 971,853.

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(21) Xue, Z.; Strouse, M. J.; Shuh, D. K.; Knobler, C. B.; Kaesz, H. D.; Hicks, R. F.; Williams, R. S. *J. Am. Chem. Soc.* **1989**, *111*, 8779–8784; contact Strem Chemicals, Inc., 7 Mulliken Way, Dexter Industrial Park, P.O. Box 108, Newburyport, MA 01950 (telephone 508-462-3191).

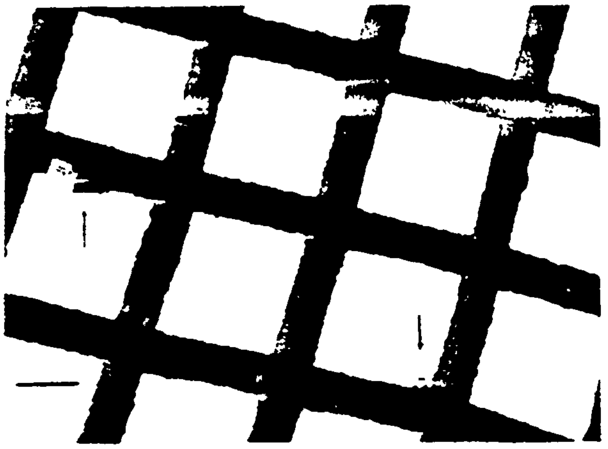

Figure 2. Transmission electron micrograph of free-standing platinum films anchored directly onto copper grids. Nodules are indicated by arrows.

Figure 3. Transmission electron micrograph of one of the nodules at higher magnification. One cluster is circled to indicate one diameter used to produce the log-normal plot.

Results

Figure 1 shows a SEM of a film deposited on a quartz window. These films have been described in detail in the context of "transparent metal" electrodes.[1] Free-standing LCVD platinum films anchored onto a standard copper TEM grid can be seen in Figure 2 at ×1500 magnification. One of those films is shown at higher magnification (×149 000) in Figure 3. The electron diffraction pattern characteristic of that particular film contains reflections[22] from only platinum, manifesting a distribution of planes and cluster sizes. The coexistence of certain perpendicular planes requires that the clusters not have much interior void volume.

At highest magnification in the TEM, dark regions having the appearance of globular clusters can be seen with brighter regions in between. As suggested by the example in the picture, these dark regions can be approximated as circular and a distribution of cluster diameters obtained. The distribution corresponding to the particular film in Figure 3 is shown in a log-normal plot in Figure 4. To obtain the histogram shown in Figure 5, all the clusters which could be clearly discerned from Figure 3 were included.

(22) ASTM X-Ray Powder Data, File No. 4-0802.

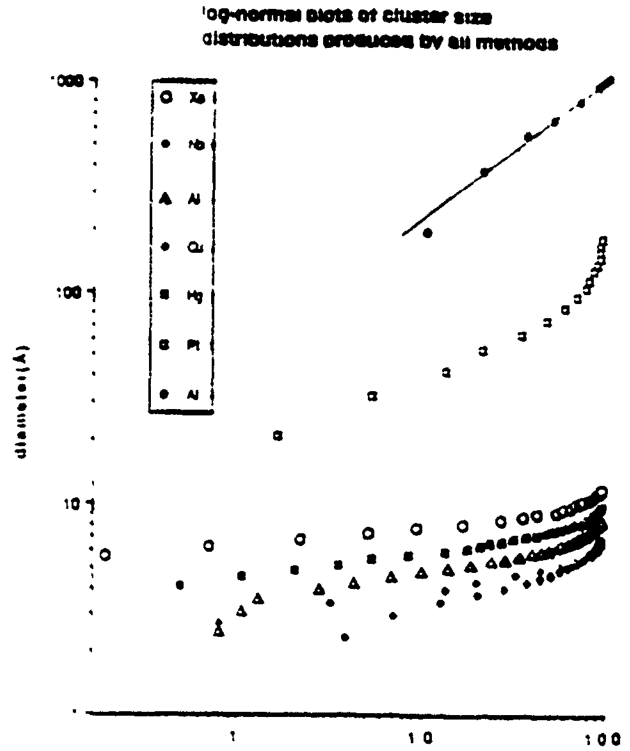

Figure 4. Typical log-normal plots of cluster distributions produced by most known methods are taken from references indicated: Xe distribution[24] produced by simple nozzle beam expansion. Hg distribution[25] produced by hybrid oven/expansion method. Pt clusters produced using laser chemistry of organometallics.[13] Al clusters produced by evaporation method[2] and also typical of sintering method results. Nb, Cu, and Al (lower) clusters[4,6] produced using laser vaporization/expansion method. For the plot corresponding to clusters produced using the evaporation method, a fitted line from the literature[4] is also shown.

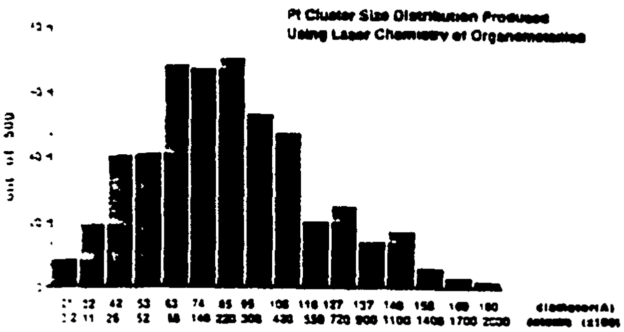

Figure 5. Histogram showing typical platinum cluster size distribution produced using laser chemistry of organometallics for one free-standing film. Using volume of sphere consistent with diameters shown and density of bulk platinum, the approximate number of atoms in each cluster is given.

Discussion

Granqvist and Buhrman[23] originally applied the log-normal distribution to differentiate between cluster size distributions produced by a coalescence growth mechanism and those produced by other mechanisms such as Ostwald ripening. One cluster distribution typical of those produced by our method, one typical of those obtained using standard sintering and evaporation methods,[2] one typical of all those[4,23] produced using the Smalley method,[24] one produced using an expansion/oven method,[25] and one produced using a supersonic expansion of Xe[26] are shown plotted together in Figure 4. These distributions span a considerable range of diameters which we believe is a measure of the number density of atoms present before coalescence and their propensity, i.e., cross section, to coalesce. All distributions taken from the literature which were produced using supersonic expansions, as well as all those we have produced to date using LCVD, reveal nonlinear log-normal plots for large cluster sizes, indicating a deficiency of larger clusters compared to what is expected based on the log-normal distribution. Since the log-normal distribution results from a statistical analysis of the evolution of the cluster size distribution, the observed deviation could be a consequence of at least a few deterministic factors.

First, we must point out that all of the gas-phase cluster distributions were obtained using time-of-flight mass spectrometry (TOF). Since TOF gives only the number of atoms directly, a cluster diameter was obtained by adding the volumes of the individual atoms and then calculating the diameter corresponding to a single sphere having this total volume. The individual atom volumes[27] used corresponded to radii obtained from X-ray diffraction studies of bulk cystalline metals, and so packing artifacts should be minimized. We are implicitly assuming that the clusters are essentially filled, but more work needs to be done to establish this assumption as a definite fact. Regardless of this, if the percentage of void volume is independent of the number of atoms in the cluster, the *shape* of the plots will be unaffected. In actual fact, using these assumptions and appropriate scaling, a careful statistical comparison of the distributions produced by expansions and laser chemistry of organometallics shows that they are identical within experimental error.

Mass spectrometric determinations of cluster distributions always present the possibility that a systematic artifact exists because clusters can fragment during ionization. A variety of schemes have been employed to minimize the effect of this potential artifact including reflection TOF mass spectrometry[25] and threshold photoionization with vacuum UV lasers. Nevertheless the possibility always exists that some artifact could exist which would incorrectly estimate the number of clusters present. In our case, the opposite possibility exists. Since the clusters come into physical contact before we estimate the distribution, the clusters could coalesce thus overestimating the number of larger clusters present compared to the nascent gas-phase distribution produced. The observed deviation from a perfect log-normal distribution suggests that just the opposite is true. A variety of reasons involving the stability of larger clusters are also plausible. For example, the particular LCVD films used in this study were produced such that the laser contacts the substrate during deposition. Thus the distribution of cluster sizes could be a measure of the propensity of certain cluster sizes to survive repeated exposure to the laser.

We also note that the artifact cor . to our LCVD and the Smalley/expansion produced distribu , could be caused by the relatively short period of time during which coalescence growth could take place. This would lead to a deficiency in larger cluster sizes relative to processes which are not kinetically quenched. The organometallic pressure is at least several orders of magnitude greater than the room-temperature vapor pressure of bulk platinum. When the laser pulse passes through, the vapor is converted to atoms and fragmented molecules. Since the effective temperature of the laser produced cloud is in the range of 10^3 K, if only because that would be the temperature needed to produce an equivalent pressure of platinum atoms starting from bulk platinum, and the coalescence occurs in the 10^{-3}–10^{-6} time scale, the cooling rate associated with LCVD is in the range 10^6–10^9 K/s. Because of the similarity between our LCVD log-normal plots and all the others, the data do support the idea that the cluster

(23) In addition to those in ref 4 see: Martin, T. P.; Bergmann, T.; Gohlich, H.; Lange, T. *J. Phys. Chem.* **1991**, *95*, 6421–6429.
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distribution we obtain for our LCVD films is determined by the properties of gas-phase clusters produced using laser chemistry of organometallics.

To attain the number densities needed to produce substantial quantities of gas-phase clusters for synthesis and reactivity studies or for film deposition, the vacuum chamber or substrate must be in contact with a relatively high ambient gas pressure. Any previously well-characterized substrate is quickly contaminated. High temperatures must be avoided for all surfaces to avoid thermal background chemistry. The rate of LCVD is limited by the rate of mass transport from the gas/mobile phase to the growing film and by the gas/mobile phase chemistry which occurs before the gas phase condenses on the substrate. Similarly, film morphology is also a direct consequence of the diffusion-limited deposition conditions.[28]

Laser chemistry of organometallics is "nonlinear" in the sense that (1) multiphoton processes can be used to generate the reactants for subsequent chemistry and also (2) because the net chemistry involves reactions between products of earlier stages with those of the later stages. Using FT-IR spectroscopy in reflectance and transmission, we have shown[29] in the present case that at least some of the allyl and cyclopentadienyl ligands are incorporated in the film as intact entities. In a previous paper,[5] we demonstrated how to remove these impurities so as to obtain nearly bulk platinum electrode characteristics from transparent platinum films. Laser chemistry of organometallics would seem to be a unique and novel type of synthetic chemistry.[30]

Conclusions

Cluster films of metals can be produced using laser chemistry of organometallics. The log-normal distribution can be used to categorize gas-phase cluster distributions produced by different synthetic methods.

Acknowledgment. We gratefully acknowledge support for this research by the donors of the Petroleum Research Fund, administered by the American Chemical Society, and by Rome Laboratory (AFOSR).

(28) In addition to a variety of fractal growth schemes (see for examples, Zumofen, G., Blumen, A., Klafter, J. *New J. Chem.* 1990, *14*, 189–196 and references therein), we have found the following reference useful: Mader, S. *Thin Solid Films* 1964, 2, 35–41.

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Nonlinear interface optical switches based on photorefractive thin films

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ABSTRACT

We present the nonlinear interface optical switch in the context of digital optical computing applications. Implications with regard to materials design and development and switch evaluation are discussed. A specific class of materials synthesized using laser chemistry of organometallics is presented. Embodiments of this type of switch have considerable potential for meeting many of the required design criteria for practical implementation of digital optical computing devices.

INTRODUCTION

We are developing and evaluating optical switches for optical computing applications which must meet a broad range of design criteria. Optical switching based on the so-called "nonlinear interface" was reported years ago[1] however finding an embodiment of that phenomenon which fullfills design criteria for actual devices remains unreported. We describe recent work on the evaluation of nonlinear interface optical switches(NIOS) based on thin films. First we give some background concerning the phenomenology of these switches and films and the concept of a nonlinear interface switch in the context of digital optical computing. We then describe the embodiment we are striving to fabricate which involves a slight digression into materials chemistry. Finally, we briefly describe current efforts toward physical evaluation of the films as switches.

BACKGROUND-NOIS

Figure 1 gives the basic idea of an NOIS. Light impinging on an interface between two media having different indices of refraction is partly reflected and partly transmitted by the interface. The percentages of the incident which are reflected and transmitted are determined by the difference in index of the refractions present at the interface. If one of the media is photorefractive, i.e. its index of refraction depends on the amount light which is present. It then becomes possible optically, to equalize the indices of refraction on either side of the interface and thereby control optical switching by controlling the amount of light reflected at the interface. A switch could be composed of a film of a photorefractive material on a transparent substrate. Standard Fresnel coefficients adequately model the observed optical performance of such films provided one knows the optical properties of the substrate, film, and air.

The optical properties of the film and substrate have to be appropriate to allow equalization of their indices of refraction by incident light. Such a device will never be a bistable device[2] regardless of the properties of available materials. The speed of the switch would depend of the temporal properties of the material(s) nonlinearity. If this were a nonresonant response, the response could be subpicosecond in both rise and fall. Similarly, the power, spectral, spatial and other switch properties would all depend on the material properties. Archetectural consideration of this type of switch has been thoroughly discussed by others[3] with the general conclusion being that the NOIS has considerable potential for digital optical computing applications. Using light from one source to control the amount of light from a different source being reflected at the interface, it is possible to construct any kind of logical function.

Since the original proposal of the NOIS by Kaplan, and the later proof of principle work by Tomlinson and coworkers, the underlying phenomenon of the NIOS has been used in a variety of other applications. Aspnes and colleagues[4] have used a phenomenon they dubbed "reflectance-difference" spectroscopy to monitor monolayer deposition of gallium and arsenic in MBE applications. Henon and coworkers[5] have used a technique they call "Brewster Angle Microscopy". Yamamoto and others have used reflection-absorption spectrometry for similar applications.

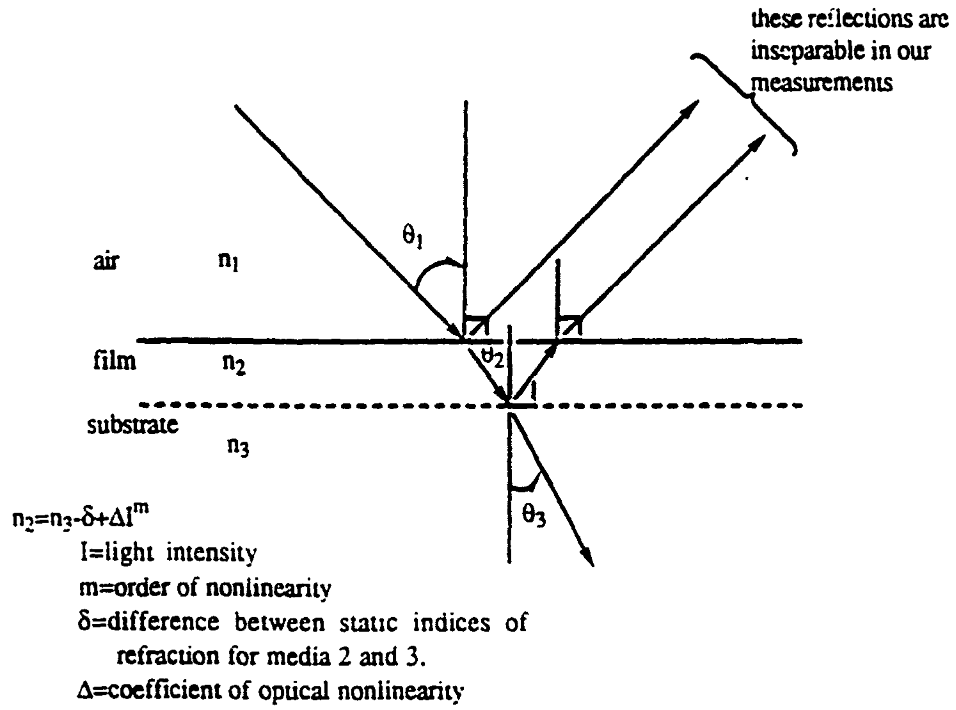

Figure 1: Interaction of light with standard three phase optical system in which the middle phase is photorefractive

In all cases, it is clear that a change in refractive index at an interface is easily detectable even for monlayer coverages of some materials on a substrate. It is also clear that two particular configurations of incident light and substrate/switch have definite advantages for maximizing the amount of light which can be switched. If the "data" light is incident on the film/substrate at or near either: 1) Brewster's angle or 2) the critical angle for total internal reflectance, then the effect of a nonlinearity in the refractive index of the film on the amount of light reflected is maximized. In principle this configuration can give switched light with zero background.

Of the many design criteria which must be met, a few would seem to be essential. For practical purposes, minimization of power dissipation and switching energy is a must. Spectral characteristics allowing integration of NOISs with SEEDs and other GaAs based devices[6] would be advantageous. Durability is a must. For the most part, thicknesses can be adjusted to enhance NOIS effects only by utilizing interference effects. Resonances tend to affect temporal characteristics adversely. Metal oxide photorefractives, e.g. niobates and titanates, would seem to exhibit adequate optical nonlinearity for many purposes provided they can be fabricated with thicknesses below ≈200 nm. This thickness would tend to be too thin to allow Fabry-Perot resonance effects in the GaAs spectral region. These and other similar considerations are straightforward to apply to all switches.

On the other hand, it is a specific characteristic of the NIOS that the initial difference in the index of refraction between the film and substrate should not be too large. The original proof of principle demonstrations utilized effects where the net photoinduced index change was only ≈0.03. The most dense and easily obtained glasses only have indices as high as ≈1.7-1.8. Thus the standard metal oxide photorefractives, which have indices which are effectively ≈2.2, do not match the properties of commercial grade quartz ≈1.56 with respect to NOIS fabrication. In actual fact, many good candidates for the photorefractive film have the disadvantage that their typical index of refraction is rather different from convenient substrates. We can envision wanting to use substrates as diverse as GaAs, Ge, quartz, or even optical plastics. We can conceive of advantages in being able to deposit switches, films directly on optical fibers. In most cases, low temperature methods for patterned deposition of refractory metal and metal oxide films do not exist.

Producing materials in thin films simultaneously displaying large optical nonlinearities, variable index of refraction and high damage thresholds has been predicted to be acheivable using clusters/ultrafine particle based materials. Many[7,8,9] have used analytic formalism and numerical simulations to show that clusters and ultrafine particles of metals, metal oxides and metal-metal oxide composites should have optical nonlinearities orders of magnitude larger than what is known for bulk samples of the same materials not having such microscopic physical morphology. For the remainder of this paper, we demonstrate that we have produced films of metal and metal oxide clusters. These films also have considerable flexibility in the bulk indices of refraction which they display. We then describe our earliest efforts at evaluating these films as optical switches.

LASER CHEMISTRY OF ORGANOMETALLICS

Metal/platinum cluster films

Clusters[10] of atoms and molecules span the transition from quantum mechanical to classical objects. Clusters and ultrafine particles have been synthesized[11,12] using sintering and heated wire evaporation, laser vaporization combined with a supersonic expansion[13], and related methods[14] which utilize ovens. We show that gas phase organometallics can be photolyzed using pulsed UV-visible lasers to initiate synthesis of metal clusters. We use the log-normal distribution function[11,12,15] to compare this new method of cluster formation to the other methods. Cluster size distributions produced using this new method bear a remarkable similarity to those produced using the nozzle beam expansion methods. Although there is some deviation from this distribution, both methods would seem to involve coalescence growth[16] as opposed to Ostwald ripening[16]. Laser chemistry allows synthesis of gas phase metal clusters because of the very high pressures of metal atoms attainable using multiphoton dissociation of organometallics.

A diagram of the basic apparatus used to perform LCVD has been presented elsewhere[17]. As can be seen in Figure 2, platinum films >550Å thick and exhibiting >70% transmittance across the entire UV-visible spectrum can be synthesized using laser chemical vapor deposition(LCVD)[17]. Such platinum films have been called 'transparent' metals[18] because they simultaneously exhibit metallic conductivity and optical transparency. The transparency is thought to be a direct consequence of 10^2 nanometer scale morphology shown using scanning electron microscopy(SEM) in Figure 3. Because of the presence of the clusters, and the diffusion controlled deposition conditions, voids are present in the films through which incident light is channeled. Smooth contiguous platinum films become opaque[18] at ≈310 Å average thickness. The clusters are thought to be highly polarizable[19] thus forcing incident electric fields into the voids.

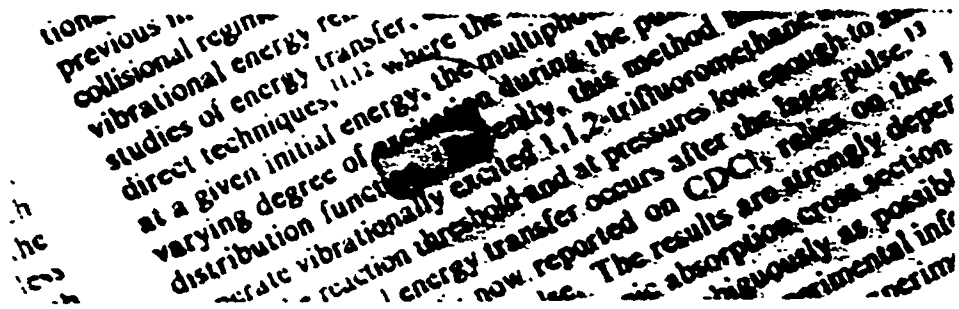

Figure 2: Photograph of "transparent" platinum film on a quartz substrate which is resting on a book page

Figure 3: SEM of platinum film on quartz substrate. Dark regions are voids which extend to substrate. Light regions are nearly pure platinum.

Puretsky and Demyanenko[20] reported over a year ago that nanosecond excimer laser pulses could be used to produce clouds of metal clusters and ultrafine particles from gas phase metal carbonyls. Their estimate on the size and shape distribution was based on mobility measurements in which the number densities and temperatures of the populations produced could not be known independently. Nevertheless, their evidence for the existence of clusters and ultrafine particles was convincing. Similar experiments were reported much earlier by Tam and coworkers[21] and others[22]. The Smalley laser vaporization/supersonic expansion technique, and oven based versions, produce collision-free gas phase samples having cluster densities of $\approx 10^{10}$ cm^{-3}. The new technique promises to allow production of gas phase number densities exceeding $\approx 10^{15}$ clusters/cm^3 using even the most refractory metals.

The organometallic precursors employed in the current study were allyl cyclopentadienyl platinum[23] and trimethyl methylcyclopentadienyl platinum[24]. Free standing platinum films anchored onto a standard copper TEM grid can be seen in Figure 4 at high magnification(x149,000). The electron diffraction pattern characteristic of that particular film contains reflections[25] from only platinum manifesting a broad distribution of planes. At highest magnification, dark regions having the appearance of globular clusters can be seen with brighter regions in between. These dark regions can be approximated as circular and a distribution of cluster diameters obtained. The distribution corresponding to the particular film is shown in Figure 5. We cannot say yet whether the clusters are hollow or solid.

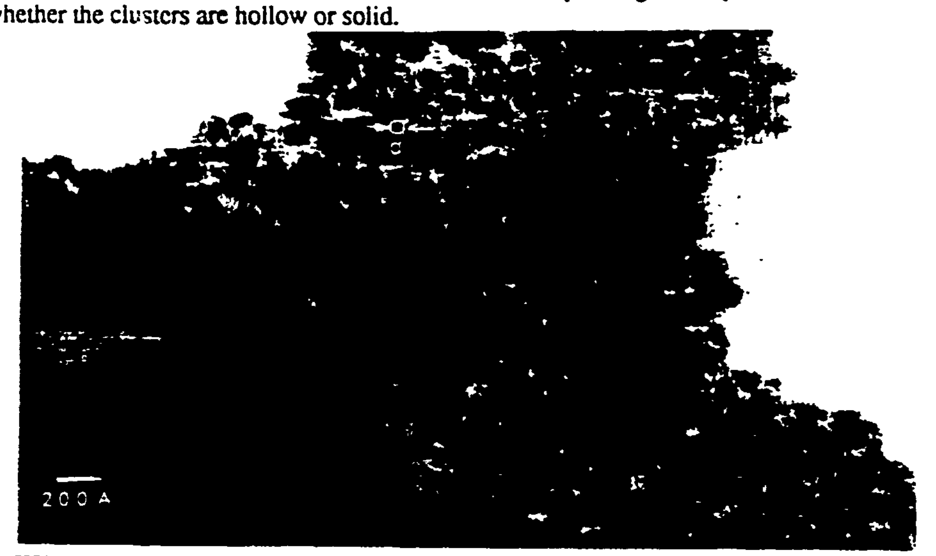

Figure 4: TEM of platinum cluster film showing diameter used to construct histogram of cluster sizes

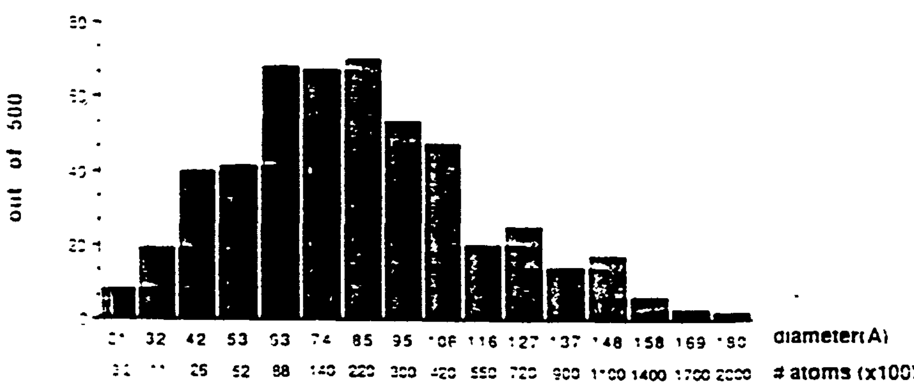

Figure 5: Histogram of cluster sizes produced in transparent platinum film.

Granqvist and Buhrman[11,12] originally applied the log-normal distribution to differentiate between cluster size distributions produced by a coalescence growth mechanism and those produced by other mechanisms such as Ostwald ripening. One cluster distribution typical of those produced by our method, one typical of those obtained using standard sintering and evaporation methods[14], one typical of all those[13-26] produced using the Smalley method, one produced using an expansion oven method[27], and one produced using a supersonic expansion of Xe[28] are shown plotted together in Figure 6. For ease in viewing, Figure 6 shows a series of log-normal expanded scale plots corresponding to distributions produced using expansions. All these distributions have very similarly shaped plots albeit the diameters span a considerable range. We believe the range spanned is a measure of the number density of metal atoms present before coalescence. All distributions that we have taken from the literature which were produced using supersonic expansions, as well as all those we have produced to date using LCVD, are nonlinear for large cluster sizes indicating a deficiency of larger clusters compared to what is expected based on the log-normal distribution. All of the gas phase cluster distributions were obtained using time of flight mass spectrometry(TOF). Since TOF only gives the number of atoms directly, a cluster diameter was obtained by adding the volumes of the individual atoms and then calculating the diameter corresonding to a single sphere having this total volume. The individual atom volumes[29] used corresponded to radii obtained from x-ray diffraction studies of bulk cystalline metals and so packing artifacts should be minimized. Regardless of this, the *shape* of the plots will be unaffected.

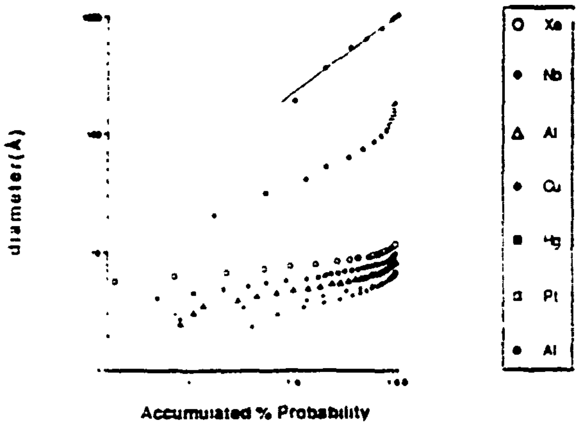

Figure 6: Log-normal plots of cluster size distributions produced by all known methods.

Mass spectrometric determinations of cluster distributions always present the possibility that a systematic artifact exists because clusters can fragment during ionization. A variety of schemes have been employed to minimize the effect of this potential artifact including reflectron TOF mass spectrometry[13,26] and threshold photoionization with VUV lasers. Nevertheless the possibility always exists that some artifact could exist which would incorrectly estimate the number of smaller clusters present. In our case, the opposite possibility exists. Since the clusters come into physical contact before we estimate the distribution, the clusters could coalesce thus over-estimating the number of larger clusters present compared to the nascent gas phase distribution produced. The observed deviation from a perfect log-normal distribution suggests that just the opposite is true. A variety of reasons involving the stability of larger clusters are also plausible. In many cases LCVD films are produced such that the laser contacts the substrate during deposition. The distribution of cluster sizes could be a measure of the propensity of certain cluster sizes to survive repeated exposure to the laser. Overall, we believe that all the data suggests that the cluster distribution we obtain for our LCVD films is mostly determined by the fact that gas phase clusters are produced using laser chemistry of organometallics.

To attain the number densities needed to produce substantial quantities of gas phase clusters for synthesis and reactivity studies or for film deposition, the vacuum chamber or substrate must be in contact with a relatively high ambient gas pressure. Any previously well characterized substrate is quickly contaminated. High temperatures must be avoided for all surfaces to avoid thermal background chemistry. The rate of LCVD is limited by the rate of mass transport from the gas/mobile phase to the growing film and by the gas/mobile phase chemistry which occurs before the gas phase condenses on the substrate. Similarly, film morphology is also a direct consequence of the diffusion limited deposition conditions[30]. Laser chemistry of organometallics is 'nonlinear' in the sense that, 1) multiphoton processes can be used to generate the reactants for subsequent chemistry and also 2) because the net chemistry involves reactions between products of earlier stages with those of the later stages. Laser chemistry of organometallics would seem to be a unique and novel type of synthetic chemistry.

Metal and metal oxide cluster films

Tungsten hexacarbonyl was purified by sublimation before being loaded into a specially designed all stainless steel gas/reactant delivery system. We have used a variety of precursors and the conditions stated here are typical. This system utilizes a molecular sieve drying tube to remove water from whatever carrier gas is used to entrain the orgaontungsten precursor. A set of

MKS capacitance manometers and isolable chambers of known volume were used to measure partial and total pressures and flow rates in the delivery system and in the deposition cell. Although this apparatus will be described in greater detail later[31], for present purposes it suffices to point out that, utilizing a series of micrometer valves and lengths of tubing with various internal diameters, the total pressure, flow rate, gas stream composition and temperature could each be independently adjusted.

Figure 7a shows a TEM of a free standing tungsten film deposited by LCVD directly onto a TEM grid at x113,000 magnification; globular clusters are clearly visible. Figure 7b shows an electron diffraction pattern obtained from the conglomeration of clusters imaged in 7a). As is typical for diffraction patterns obtained from many such conglomerations, the near coalescence of the diffraction rings into spots presents an interesting comparison with the results of Mader[32] and Aspnes.[33] Observation of "implied" rings is consistent with the idea that our films are composed by condensation of clusters of varying sizes. The spacings between the rings were analyzed and only interplanar spacings of tungsten are evident[34]. These spacings would seem to be characteristic of the environment *inside* the clusters. The tungsten clusters are produced using 20 millitorr of tungsten hexacarbonyl at 62°C with argon added to produce a total pressure of 70 mtorr in the deposition cell. This pressure is lower than the vapor pressure of bulk tungsten hexacarbonyl at the same temperature because we are working in a flowing cell. Figures 7c and 7d show essentially the same data obtained for tungsten oxide clusters. These clusters were deposited using the same partial pressure of tungsten hexacarbonyl but with the rest of the total pressure being composed using O_2. For the oxide clusters, the diffuse quality of the rings suggests less order within the clusters as well as a distribution of sizes. Raman spectra of films composed of these clusters have extensive structure below ≈400 cm^{-1} but absolutely no hint of the well known, and extremely strong 700-900 cm^{-1} features indicative of the presence of WO_6 octahedra. Auger analysis(internally calibrated against authentic W, WO_2 and WO_3) of these oxide films reveals an average W:O stoichiometry 1:1.5 which is a factor of ≈10 below the gas phase ratio present during LCVD. The film W:O ratio varies widely from spot to spot on the film and can range from ≈1:2.5 to nearly 1:1. Measurements of the temperature dependence of the resistivity of 200 nm thick films on quartz in air reveals irreversible changes occurring at temperatures as low as ≈100°C. The resistivity of nascent films, which are semiconductors, exceeds that of polycrystalline tungstate films although the implied band gap(.15 eV) is typical[35].

The single most important aspect of all the materials describe above is that the bulk indices of refraction can be chosen by deposition conditions. The platinum films typically have low power indices of refraction(6328Å) in the range of ≈2.0 compared to a value for bulk platinum of ≈3.8. Similarly, the index of refraction obtained for the laser deposited tungsten and tungsten oxide films using a CW HeNe laser range from nearly 1.0 to 2.2. The bulk refractive index for sputtered polycrystalline tungstate films is in the range of 2.3 to 2.5. In all cases, the variation in index of refraction in easily rationalized[18] on the basis of the effective medium theory and the void volume of the films. Since deposition of the films is entirely diffusion controlled, deposition conditions determine the void volume which in turn affects the bulk index of refraction. As detailed above, this situation is extremely useful for engineering film for NOIS applications.

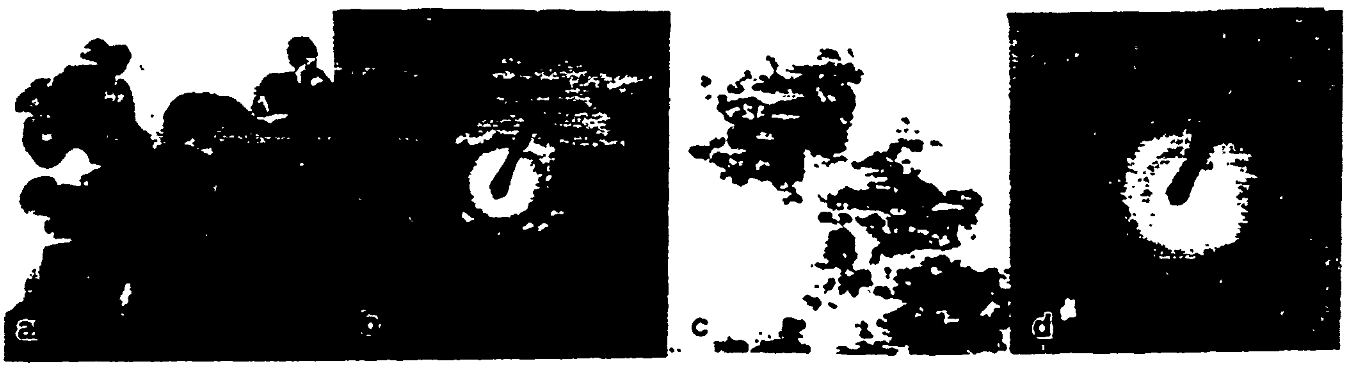

Figure 7 TEM and electron diffraction characterization of tungsten(a,b) and tungsten oxide(c,d) cluster films

Optical Switch Evaluation

Evaluation of potential switches fabricated using films of the above materials is currently in progress and so only the general ideas will be presented here. Two configurations are used as embodiments of switches. The light can impinge on the film and then the substrate as suggested by Figure 1. In all cases, the reflections from the air-film interface cannot be separated from the reflection at the film-substrate interface. However, careful nearly zero background measurements can be made when the angle of incidence is adjusted to be near the effective Brewster angle for the film-air system. Alternatively, it is possible to proceed with an exactly reversed situation. In this case the light enters the switch from the uncoated side of the substrate and is propagated until it encounters the film-substrate interface. The angle of incidence of the light with the substrate is varied until the critical angle for total internal reflection for the light at the film-substrate interface is acheived. In this case the percentage of light transmitted across the substrate-film-air interface is measured as a function of incident power. This latter configuration is also a nearly zero background measurement and in practice is less sensitive to photorefractive effects at the film-air interface.

In either configuration, the starting point for switch evaluation is contained in Figure 8 which shows results of a measurement of the percent reflectance of the film-substrate combination as a function of incident angle. The film is composed of the tungsten oxide clusters shown above. The simplest point to make is that if the shape of such a curve is a function of the power of the incident light, then one of the materials in the three phase system is photorefractive and switching is possible. We have been engaged in measureing the power dependence of the shapes of such curves at a variety of wavelengths. We have been using mode-locked 514 nm pulses of ≈100 psec duration obtained from an argon ion although measurements at different wavelengths will be conducted soon. Once a photorefractive effect is detected, then the switch can be evaluated in the typical pump probe method in which a pulse of light is used to set-up the photorefractive effect and a later pulse, the probe/data arrives delayed to manifest the presence of the earlier pulse. These measurements are the starting point for complete spectral, spatial, temporal and energetic evaluation of NOIS devices.

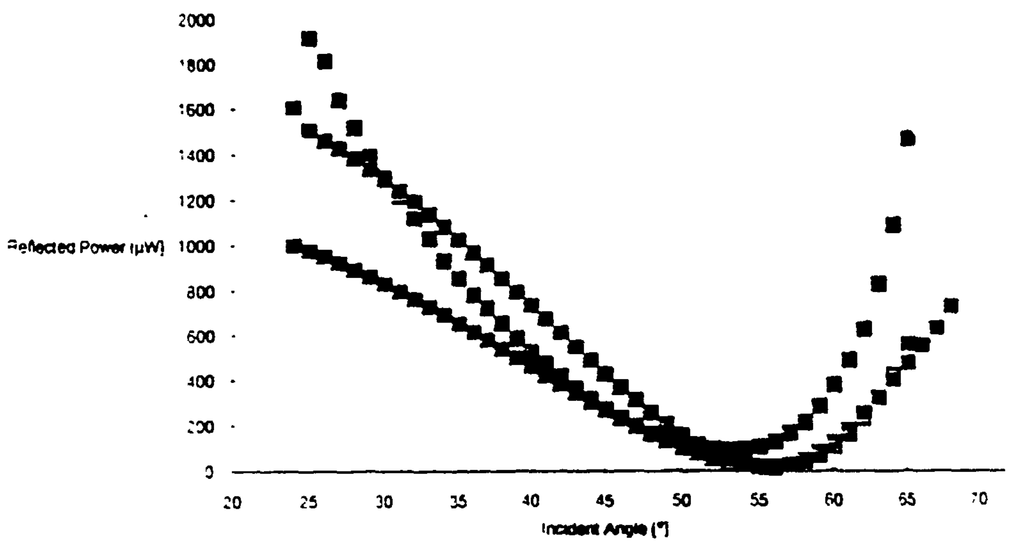

Figure 8 Typical power reflected from a tungsten oxide cluster film as a function of angle of incidence.

Conclusions

Optical switches based on nonlinear interfaces have considerable promise towards meeting the myriad of design criteria for producing devices relevant to digital opticla computing applications. Novel materials which can only be synthesized using laser chemistry of organometallics have a number of unique advantages for the design and fabrication of such switches. Switch evaluation is proceeding using metal and metal oxide cluster films which have been predicted to be highly photorefractive.

Acknowledgements

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Session 16 - Photonics
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An Optical Nor Gate Based on GaAs-AlGaAs Heterostructure Lasers

M.A. Parker and S. Libby, *Rome Laboratory*
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PAPER INCLUDED

Nonlinear Interface Optical Switches Based on Photorefractive Thin Films

M.J. Casey, Joseph Chaiken, *Syracuse University*
Joseph Osman, *Rome Laboratory*

PAPER INCLUDED

Optical Interconnects for High Speed 3-D Signal Processors

David Honey and Franz Haas, *Rome Laboratory*
David Mikolas and Harold Craighead, *Cornell University*

Processing focal plane data via optically interconnected 3-D computers offers potential for meeting high speed computational requirements without a large power budget. Design, fabrication and test results of one such optical bus, based on reflective binary optical elements etched in silicon and supporting a stacked wafer 3-D design, are discussed.

Massive Holographic Interconnections for Use in a Low Energy Optical Processor

David R. Christie, *Rome Laboratory*
Stephen A. Kupiec, *University of Alabama at Huntsville*

An N^4 holographic free space optical interconnection scheme in a special purpose processor architecture allows massive parallel calculations at very low energy cost. Initial testing of resolution, error resiliency, and diffraction efficiency for a system employing a 256 x 256 pixel Spatial Light Modulator (SLM) and incorporating noise- and crosstalk-minimization techniques is discussed.

A Reprogrammable Digital Optical Coprocessor

James M. Battiato, Rebecca J. Bussjager and Joseph. M. Osman, *Rome Laboratory*

A hybrid electro-optical digital computer incorporating a fully digital free space Optical Programmable Logic Array (OPLA) as a coprocessor for an electronic host is described. OPLA architectures are evaluated and compared to electrical PLAs. Fabrication considerations and applications are discussed.

NONLINEAR INTERFACE OPTICAL SWITCHES BASED ON PHOTOREFRACTIVE THIN FILMS

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ABSTRACT

We present the nonlinear interface optical switch in the context of digital optical computing applications. Implications with regard to materials design and development and switch evaluation are discussed. A specific class of materials synthesized using laser chemistry of organometallics is presented. Embodiments of this type of switch have considerable potential for meeting many of the required design criteria for practical implementation of digital optical computing devices.

INTRODUCTION

We are developing and evaluating optical switches for optical computing applications which must meet a broad range of design criteria. Optical switching based on the so-called "nonlinear interface" was reported years ago[1] however finding an embodiment of that phenomenon which fulfills design criteria for actual devices remains unreported. We describe recent work on the evaluation of nonlinear interface optical switches(NICS) based on thin films. First we give some background concerning the phenomenology of these switches and films and the concept of a nonlinear interface switch in the context of digital optical computing. We then describe the embodiment we are striving to fabricate which involves a slight digression into materials chemistry. Finally, we briefly describe current efforts toward physical evaluation of the films as switches.

BACKGROUND-NIOS

Figure 1 gives the basic idea of an NIOS. Light impinging on an interface between two media having different indices of refraction is partly reflected and partly transmitted by the interface. The percentages of the incident which are reflected and transmitted are determined by the difference in index of the refractions present at the interface. If one of the media is photorefractive, i.e. its index of refraction depends on the amount of light which is present,it then becomes possible optically, to equalize the indices of refraction on either side of the interface and thereby control optical switching by controlling the amount of light reflected at the interface. A switch could be composed of a film of a photorefractive material on a transparent substrate. Standard Fresnel coefficients adequately model the observed optical performance of such films provided one knows the optical properties of the substrate, film, and air.

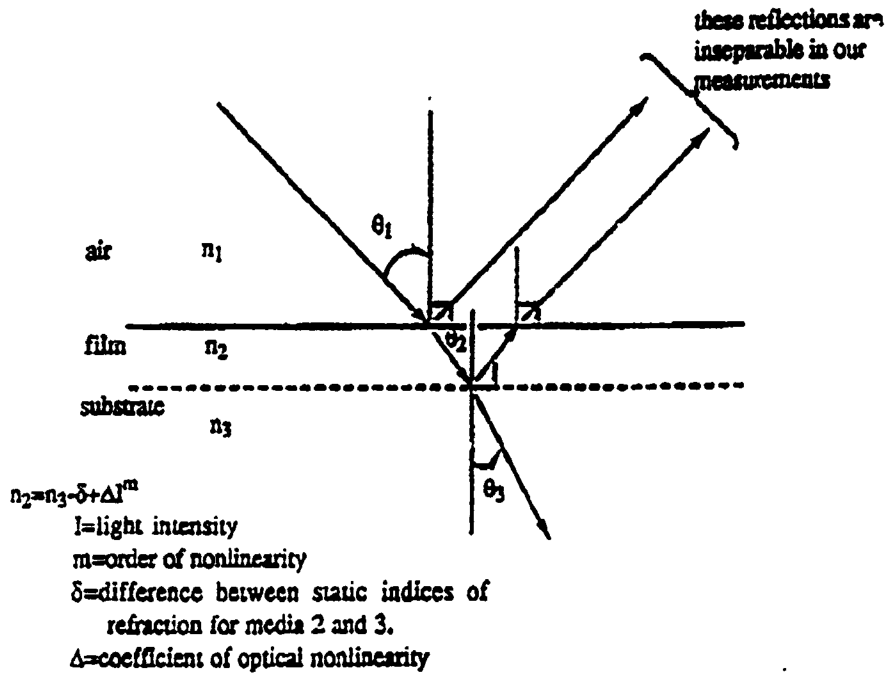

Figure 1: Interaction of light with standard three phase optical system in which the middle phase is photorefractive

Of the many design criteria which must be met, a few would seem to be essential. For practical purposes, durability, minimization of power dissipation and switching energy is a must. Spectral characteristics allowing integration of NIOSs with SEEDs and other GaAs based devices[2] would be advantageous. The optical properties of the film and substrate have to be appropriate to allow equalization of their indices of refraction by incident light. The initial difference in the index of refraction between the film and substrate should not be too large. The original proof of principle demonstrations utilized effects where the net photoinduced index change was only ≈0.03. Such a device will never be a bistable device[3] regardless of the properties of available materials. The speed of the switch would be optimized using a nonresonant nonlinear response. Architectural consideration of this type of switch has been thoroughly discussed by others[4] with the general conclusion being that the NIOS has considerable potential for digital optical computing applications. Using light from one source to control the amount of light from a different source being reflected at the interface, it is possible to construct any kind of logical function.

Since the original proposal of the NIOS by Kaplan, and the later proof of principle work by Tomlinson and coworkers, the underlying phenomenon of the NIOS has been used in a variety of other applications. Aspnes and colleagues[5] have used a phenomenon they dubbed "reflectance-difference" spectroscopy to monitor monolayer deposition of gallium and arsenic in MBE applications. Henon and coworkers[6] have used a technique they call "Brewster Angle Microscopy". Yamamoto and others have used reflection-absorption spectrometry for similar applications.

In all cases, it is clear that a change in refractive index at an interface is easily detectable even for monolayer coverages of some materials on a substrate. It is also clear that two particular configurations of incident light and substrate/switch have definite advantages for maximizing the amount of light which can be switched. If the "data" light is incident on the film/substrate at or near either: 1) Brewster's angle or 2) the critical angle for total internal reflectance, then the effect of a nonlinearity in the refractive index of the film on the amount of light reflected is maximized. In principle this configuration can give switched light with zero background.

Producing materials in thin films simultaneously displaying large optical nonlinearities, variable index of refraction and high damage thresholds has been predicted to be achievable using clusters/ultrafine particle based materials. Many[7,8,9] have used analytic formalism and numerical simulations to show that clusters and ultrafine particles of metals, metal oxides and metal-metal oxide composites should have optical nonlinearities orders of magnitude larger than what is known for bulk samples of the same materials not having such microscopic physical morphology. For the remainder of this paper, we demonstrate that we have produced films of metal and metal oxide clusters. These films also have considerable flexibility in the bulk indices of refraction which they display. We then describe our earliest efforts at evaluating these films as optical switches.

LASER CHEMISTRY OF ORGANOMETALLICS

A diagram of the basic apparatus used to perform Laser Chemical Vapor Deposition (LCVD) has been presented elsewhere[10]. Details concerning the cluster size distribution and underlying chemical considerations are given in refereed publications[11]. For present purposes, tungsten hexacarbonyl was purified by sublimation before being loaded into a specially designed all stainless steel gas/reactant delivery system. We have used a variety of precursors and the conditions stated here are typical. This system utilizes a molecular sieve drying tube to remove water from whatever carrier gas is used to entrain the organotungsten precursor. A set of MKS capacitance manometers and isolable chambers of known volume were used to measure partial and total pressures and flow rates in the delivery system and in the deposition cell. Although this apparatus will be described in greater detail later[12], for present purposes it suffices to point out that, utilizing a series of micrometer valves and lengths of tubing with various internal diameters, the total pressure, flow rate, gas stream composition and temperature could each be independently adjusted.

Figure 7a shows a TEM of a free standing tungsten film deposited by LCVD directly onto a TEM grid at x113,000 magnification; globular clusters are clearly visible. Figure 7b shows an electron diffraction pattern obtained from the conglomeration of clusters imaged in 7a). As is typical for diffraction patterns obtained from many such conglomerations, the near coalescence of the diffraction rings into spots presents an interesting comparison with the results of Mader[13] and Aspnes.[14] Observation of "implied" rings is consistent with the idea that our films are composed by condensation of clusters of varying sizes. Figures 7c and 7d show essentially the same data obtained for tungsten oxide clusters. These clusters were deposited using the same partial pressure of tungsten hexacarbonyl but with the rest of the total pressure being composed using O_2. The single most important aspect of all the materials describe above is that the bulk indices of refraction can be chosen by deposition conditions. The index of refraction obtained for the laser deposited tungsten and tungsten oxide films using a CW HeNe laser range from nearly 1.0 to 2.2. The bulk refractive index for sputtered polycrystalline tungstate films is in the range of 2.3 to 2.5. In all cases, the variation in index of refraction in easily rationalized[18] on the basis of the effective medium theory and the void volume of the films. Since deposition of the films is entirely diffusion controlled, deposition conditions determine the void volume which in turn affects the bulk index of refraction. As detailed above, this situation is extremely useful for engineering film for NIOS applications.

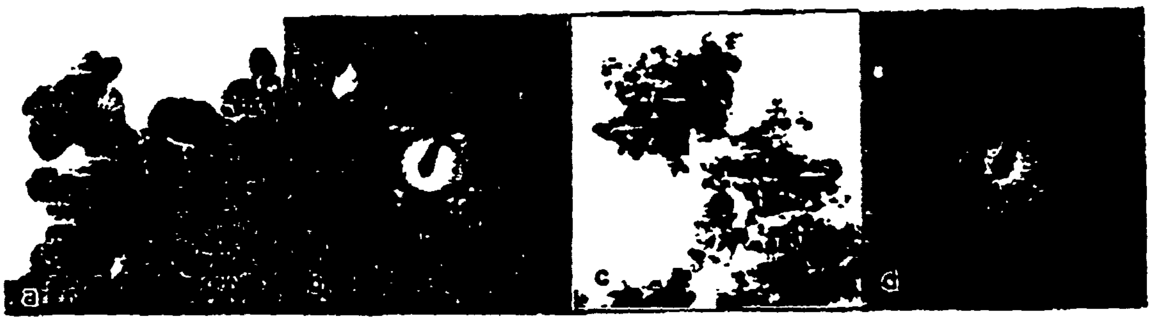

Figure 2 TEM and electron diffraction characterization of tungsten(a,b) and tungsten oxide(c,d) cluster films

Optical Switch Evaluation

Evaluation of potential switches fabricated using films of the above materials is currently in progress and so only the general ideas will be presented here. Two configurations are used as embodiments of switches. The light can impinge on the film and then the substrate as suggested by Figure 1. In all cases, the reflections from the air-film interface cannot be separated from the reflection at the film-substrate interface. However, careful nearly zero background measurements can be made when the angle of incidence is adjusted to be near the effective Brewster angle for the film-air system. Alternatively, it is possible to proceed with an exactly reversed situation. In this case the light enters the switch from the uncoated side of the substrate and is propagated until it encounters the film-substrate interface. The angle of incidence of the light with the substrate is varied until the critical angle for total internal reflection for the light at the film-substrate interface is achieved. In this case the percentage of light transmitted across the substrate-film-air interface is measured as a function of incident power. This latter configuration is also a nearly zero background measurement and in practice is less sensitive to photorefractive effects at the film-air interface.

In the present case, as suggested by Figure 1, at a given laser intensity the switches can be easily modelled using Fresnel coefficients. At a given laser intensity, the indices of refraction can be taken to be simple scalar constants. The net reflectance of a switch is then only a function of the angle θ_1, n_1, n_2, n_3 and the thickness of the film. This three phase system has been dealt with by Fendler and coworkers[15] using Fresnel coefficients, with the following useful result. If the film is nonabsorbing, and interference effects can be neglected, it can be shown that if the reflectance of the air-film-substrate system is measured as a function of θ_1, and the reflectance is measured for the simpler air-substrate system as a function of θ_1, then two curves are obtained which cross at the crossover angle α such that

$$n_2 = \tan \alpha$$

In this way we measured n_2 for a range of incident laser intensities. If the film is photorefractive, then α depends on I.

The reflected power was measured as a function of incident angle for 514 nm 120 ps duration pulses with a pulse repetition frequency of 82 MHz from a mode-locked argon ion laser. Typical reflectance versus incident angle curves for both the two phase and three phase systems at two different laser powers are shown in figure 8. This was done for 10 different levels of incident power, from a minimum average power of 1 mW to a maximum of 235 mW, all with a beam size of approximately 100 µm.

Figure 9 shows the calculated n_2 for each laser power. This figure clearly shows the index of refraction is a function of laser power even at low power. In the middle of the power range used, the peak power is only in the $10\text{-}10^2$ W range. The intensity is only about 2×10^5 W/cm^2.

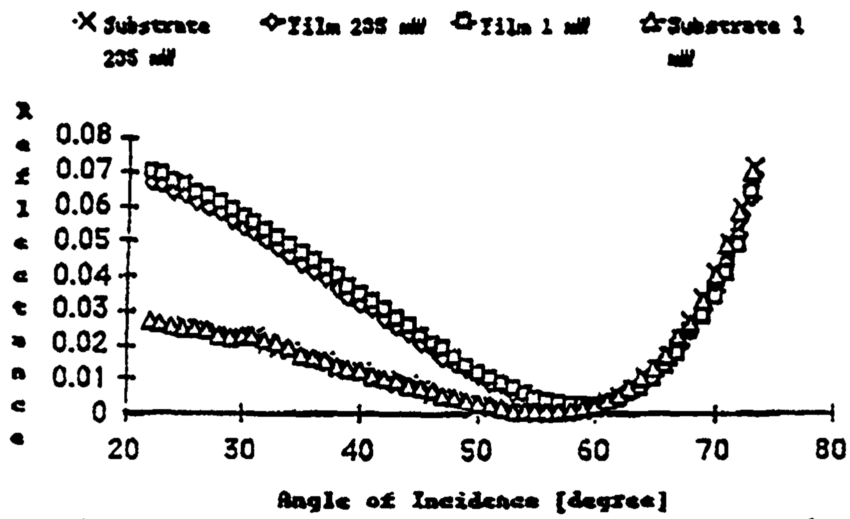

Figure 8. Reflectance from a tungsten oxide cluster film as a function of angle of incidence and incident power.

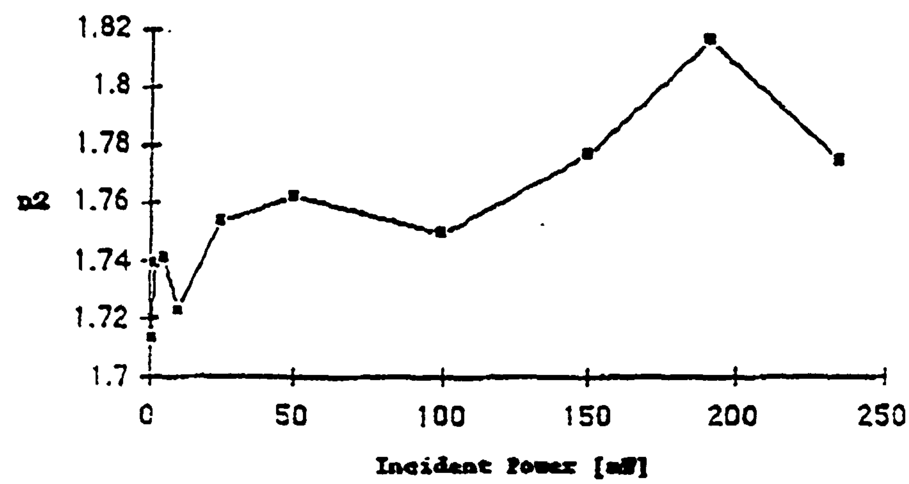

Figure 9. Index of refraction as a function of incident power from film-substrate crossover angle data.

Now that a nonlinear effect has been detected, the next step is to determine the time scale of the nonlinearity at different wavelengths. This will be accomplished by using a "pump" pulse to initiate the nonlinearity, then following the "pump" pulse with a probe pulse to investigate the changes in the film due to the "pump" pulse. We plan to examine the nonlinear response using our single shot to kHz pulse selection capability. To examine the source and order of the nonlinearity we can measure in greater precision and detail the power dependence of n_2. The high speed laser facility at Rome Laboratory has a system capable of 0.6 fs resolution in the pump-probe delay, and a femtosecond pulse capability of < 100 fs at 620 nm and from 700-900 nm. It also has a < 10 ps capability from 200-1100 nm.

These measurements will be the starting point for complete spectral, spatial, temporal and switching energy evaluation of NIOS devices. Considering that we are only in the earliest stages of materials development, the admittedly preliminary results are extremely encouraging.

Conclusions

Optical switches based on nonlinear interfaces have considerable promise towards meeting the myriad of design criteria for producing devices relevant to digital optical computing applications. Novel materials which can only be synthesized using laser chemistry of organometallics have a number of unique advantages for the design and fabrication of such switches. In agreement with theoretical predictions metal oxide cluster films would seem to be highly photorefractive.

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